N E W M E X I C O

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Alamogordo	-	19,21	4
Albuquerque	2,4,5,7	-	35
Artesia	-	26,28	4
Belen	-	22,24	3
Bernalillo	-	20	2
Carlsbad	10	22,24	7
Carrizoza	-	42	1
Chama	-	43	0.7
Clayton	-	27	3
Clovis	12	14,16	10
Dawson	-	41	2
Deming	-	23,25	4
Farmington	-	21	2
Ft. Sumner	-	43	2
Gallup	3,10	17,19	7
Hachita	-	[illegible]	0.8
Hobbs	-	15,17	11
Hot Springs	-	[illegible]	3
Laguna	-	28	0.5
Lordsburg	-	43,45	3
Los Alamos	-	34	?
Las Cruces	-	27,29	8
Las Vegas	-	17	6
Lovington	-	30	2
Magdalena	-	35	1
Park View	-	36	5
Portales	-	18,20	0.8
Raton	-	35,37	8
Roswell	3,6,8	34,36	13
Roy	-	44	1
San Rita	-	20	3
Santa Fe	9,11,13	30,32	20
Santa Rosa	-	25	2
Silver City	12	18	5
Socorro	-	14,16	4
Taos	-	15	1
Tucumcari	-	29,31	6
Vaughn	-	45	1
Willard	-	39	0.5

PROPOSED

NEW YORK

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Albany-Schenectady-Troy	4	42,44	432
Auburn	-	18	36
Batavia	-	36	17
Binghamton	12	23,25	145
Buffalo - Niagara	2,4,7	27	857
Dunkirk	-	31	18
Elmira - Corning	-	14,16	61
Hornell	-	39	17
Ithaca	-	37	20
Jamestown	-	17	43
Malone	-	30	9
Massena	-	21	11
Middletown	-	35	22
New York City/Northeastern N.J.	2,4,5,7,9,11	-	11,691
Ogdensburg	-	34	16
Olean	-	[illegible]	22
Oneonta	-	[illegible]	12
Oswego	-	[illegible]	22
Plattsburg	-	32	16
Poughkeepsie	-	40	40
Rochester 2/	5	22,32,44	412
Saranac Lake	-	39	7
Syracuse 3/	3,8,10	-	258
Tupper Lake	-	19	5
Utica - Rome	13	33	197
Watertown	-	41,43	33

PROPOSED

2/ See paragraphs 6, 7 & 9 of the Notice of Further Proposed Rule Making to which this appendix is attached.

3/ See paragraphs 6, 7 & 8 of the Notice of Proposed Rule Making to which this appendix is attached.

N O R T H   C A R O L I N A

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Ahoski	0	39	2
Asheville	0	14,18	51
Belhaven	0	20	2
Charlotte	3,9,11	0	101
Durham	0	33,35	60
Elizabeth City	0	31	12
Fayetteville	0	38,40	17
Gastonia	0	42	21
Goldsboro	0	26	17
Greensboro	2	41,43,45	59
Greenville	0	36	13
Henderson	0	18	8
Hendersonville	0	20	8
Hickory	0	34	13
High Point	0	23,25	38
Jacksonville	0	22	1
Kannapolis	0	[illegible]	25
Kinston	0	[illegible]	15
Lenoir	0	36	8
Morehead City	0	45	4
New Bern	0	32	12
Raleigh	0	28,30	47
Rocky Mount	0	24	26
Salisbury	0	21	19
Shelby	0	44	14
Wilmington	5	14,16	33
Wilson	0	44	19
Winston Salem	6,13	17	80
Washington	0	34	9

PROPOSED

NORTH DAKOTA

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Ashley	-	36	1
Bismarck	5,7,12	20,22	15
Botteneau	-	32	2
Bowman	-	43,45	1
Carrington	-	17	1
Cooperstown	-	28	1
Crosby	-	36,38	1
Devils Lake	-	19	6
Dickinson	2,4,9	-	6
Fargo	6,10,13	14,16,18	33
Ft. Yates	-	29	1
Grafton	-	26,30	4
Grand Forks	2,4,8	33,35,39	20
Harvey	-	44	2
Hettinger	-	32,34	1
Jamestown	-	[illegible]	9
Kenmore	-	30	2
Langdon	-	41,43	2
Larimore	-	49	1
Mandan	-	33,35,37	7
Minot	3,6,10	16,18	17
Napoleon	-	27	1
New Rockford	-	15	2
Oakes	-	40,42	2
Rolla	-	23	1
Rugby	-	21	2
Stanley	-	42	1
Stanton	-	14	4
Valley City	-	31	6
Wahpeton	-	34	4
Williston	8,11	23,25,27	6

PROPOSED

O H I O

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Akron	-	25,36,38	349
Canton	-	32,34	200
Chilicothe	-	37	20
Cincinnati	4,7,11	22,24	789
Cleveland /4	4,5,8,11	40,42	1,214
Columbus	3,6,10	-	365
Dayton	5,13	14,16	271
Gallipolis	-	27	7
Hamilton-Middletown	2	34	112
Lima	-	28,30	44
Mansfield	-	21,23	37
Marion	-	33,35	30
Newark	-	29	31
Portsmouth	-	18,20	40
Sandusky-Fremont	-	17	25
Springfield	-	[illegible],44	77
Steubenville	-	[illegible]	37
Toledo	13	[illegible]	341
Youngstown	-	14,16,18	372
Zanesville	-	15	37

/4 See paragraphs 6,7 and 10 of the Notice of Further Proposed Rule Making to which this Appendix C is attached.

O K L A H O M A

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Ada	-	20	15
Altus	-	16	9
Alva	-	23	5
Ardmore	-	32	17
Bartlesville	-	14	16
Beaver	-	36	1
Boise City	-	30	1
Chickasha	-	45	14
Clinton	-	31	7
Duncan	-	35	9
Durant	-	40	10
Elk City	-	14	5
El Reno	-	22	10
Enid	13	15	28
Frederick	-	27	5
Guthrie	-	[illegible]	10
Guymon	-	20	2
Hobart	-	25	2
Hugo	-	[illegible]	6
Lawton	10	18	18
Miami	-	36	8
Muskogee	8	23	32
McAlester	-	34	12
Norman	-	41	11
Okeene	-	29	4
Oklahoma City	4,7,9	-	221
Okmulgee	-	28	16
Ponca City	-	27	17
Seminole	-	43	12
Shattuck Jnc.	-	40	1
Shawnee	-	30	22
Stillwater	-	17	10
Tulsa	2,6,11	-	189
Woodward	-	45	5

PROPOSED

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O R E G O N

PROPOSED

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Albany	-	25	6
Ashland	-	19,21	5
Astoria	-	26	10
Baker	-	16	9
Bend	-	28,35	10
Burns	-	21,42	3
Canyon City	-	14	0.3
Coquille	-	24,26	3
Condon	-	22	1
Corvallis	-	23	8
Enterprise	-	40	2
Eugene	-	14,16	21
Gold Beach	-	40	.5
Grants Pass	-	36,38	6
Heppner	-	41,43	1
Hood River	-	36	3
Kinzua	-	18	0.8
Klamath Falls	2,4	32,34	16
La Grande	3,13	-	8
Lakeview	-	20,27,29	2
McMinnville	-	44	4
Madras	-	39	0.4
Marshfield (Coos Bay)	-	22,29	5
Medford	5,7	15,17	11
Newport	-	42	2
Ontario	-	20	4
Pendleton	-	24	9
Portland	3,6,8,10,12	17	406
Pineville	-	30	2
Redmond	-	45	2
Reedsport	-	18	1
Roseburg	-	31,33	5
Salem	-	32,34	31
Sprague River	-	41,43	6
The Dalles	-	27	6
Tillamook	-	19,21	3
Westfir	-	37	0.8

P E N N S Y L V A N I A

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Altoona	0	15	114
DuBois	0	43	12
Easton-Allentown-Beth.	0	19,21	325
Emporium	0	33	4
Erie	12	45	134
Greensburg	0	48	17
Harrisburg	0	22,42	173
Hazelton	0	38	38
Johnstown	6,13	21	152
Lancaster /5	4	26,28	132
Lebanon	0	24	27
Lewistown	0	40	13
Meadville	0	47	19
New Castle	0	30	48
Philadelphia	3,6,10	44	2,899
Pittsburgh	3,9	24,26	1,994
Reading	0	34,36	175
Scranton-Wilkes Barre	0	31,45	630
Uniontown	0	46	22
Williamsport	0	29	44
York	6	18,20	93

PROPOSED

R H O D E I S L A N D

Providence	11	15,17	712

S O U T H C A R O L I N A

Anderson	0	33	19
Barnwell	0	25	2
Bennettsville	0	15	5
Charleston	2,8,13	28,30	71
Columbia	4,7,10	39	62
Florence	0	27	16
Georgetown	0	18	6
Greenville	0	38,40	35
Greenwood	0	31	13
Myrtle Beach	0	37	2
Orangeburg	0	45	11
Rockhill	0	29	15
Seneca	0	35	2
Spartanburg	0	22,24	32
Sumter	0	32	16
Walterboro	0	34	3

/5 See asterisk footnote to Section III - F - 1 in Appendix A which is part of the notice of Further Proposed Rule Making herein.

S O U T H   D A K O T A

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Aberdeen	3,9	26,30	17
Belle Fourche	-	20	3
Brookings	-	41,43,45	5
Buffalo	-	30	0.5
Chamberlin	-	23	2
Custer	-	16	2
Deadwood	-	35	4
Dupree	-	17	0.5
Edgemont	-	39,41	2
Gettysburg	-	19	1
Hot Springs	-	33	3
Huron	-	32,35	11
Lake Andes	-	27	0.8
Lead	-	27	8
Madison	-	37,39	5
Martin	-	21	1
Mobridge	-	39,41	3
Miller	-	25	1
Mitchell	4,8	-	11
McIntosh	-	24	0.6
Phillip	-	14	0.8
Pierre	6,10	-	1
Pine Ridge	-	43,45	2
Rapid City	7,12	-	14
Sioux Falls	11,13	14,16,18	41
Sisseton	-	44	2
Vermillion	-	31,33	3
Watertown	-	22,24	11
White River	-	21	0.6
Winner	-	42,44	2
Yankton	-	25,29	7

PROPOSED

T E N N E S S E E

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Bristol	0	26	14
Chattanooga	3,9,12	0	193
Clarksville	0	42	12
Cleveland	0	30	11
Columbia	0	21	11
Cookeville	0	37	4
Dyersburg	0	30	10
Fayetteville	0	16	5
Harriman	0	17	6
Humboldt	0	35	5
Jackson	0	24	24
Johnson City	0	16	25
Knoxville	6,10,13	0	152
Lebanon	0	27	6
Lewisburg	0	29	4
Lexington	5	0	3
Memphis	4,6,8,10,13	0	332
Morristown	0	43	8
Murfreesboro	0	14	9
Nashville	2,4,7,11	0	242
Paris	0	19	6
Pulaski	0	38	5
Shelbyville	0	31	7
Springfield	0	23	7
Tullahoma	0	33	5
Union City	0	28	7
Winchester	0	18	3

TEXAS

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Abilene	9	24	27
Alice	0	19	8
Alpine	12	0	4
Amarillo	2,4,5,7,10	0	53
Athens	0	41	5
Austin	0	26,28,30	106
Ballinger	0	36	4
Bay City	0	16,40	7
Beaumont/ Port Arthur	4,6	26,33,39	139
Beeville	0	25	7
Big Spring	0	25	13
Borger	0	15	10
Brackittville	0	29	3
Brady	0	19	5
Breckenridge	0	17	6
Brenham	0	19	6
Brownfield	0	37	4
Brownville	4,5,9	0	22
Brownwood	0	21	13
Bryan	0	14	12
Cameron	0	32	5
Canadian	0	28	2
Canyon	0	32	3
Center	0	40	3
Childress	0	19	6
Clarendon	0	26	2
Cleburne	0	44	11
Coleman	0	43	6
Colorado City	0	18	5
Corpus Christi	6,10	31,33	71
Cotulla	0	32	4
Crockett	0	22	5
Crystal City	0	24	7
Cuero	0	20	5
Dalhart	0	22	5
Dallas	4,8,12	0	377
Del Rio	0	18	13
Denton	0	36	11
Dumas	0	45	2
Eagle Lake	0	29	2
Eagle Pass	0	16	6
Edinburg	0	21	9
El Campo	0	38	4
Eldorado	0	33	2
El Paso	2,4,5,7,9	41,44	116

PROPOSED

T E X A S (CONTD)

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Falfurrias	-	23	6
Ft. Davis	-	14	1
Ft. Stockton	-	31	3
Ft. Worth	2,5,10	--	208
Fredericksburg	-	22	4
Galveston	-	21,24	72
Graham	-	15	5
Greenville	-	24	14
Gonzales	-	15	5
Hamilton	-	39	3
Hamlin	-	28	2
Harlingen	-	14	13
Haskell	-	30	3
Henrietta	-	23	2
Hereford	-	42	3
Hillsboro	-	25	8
Houston	2,8,11,13	[illegible]	510
Huntsville	-	[illegible]	5
Jacksonville	-	15	7
Jasper	-	--	3
Junction	-	27	2
Kermit	-	38	3
Kerrville	-	17,31	6
Kilgore	-	43	7
Kingsville	-	17	8
La Grange	-	43	3
Lamesa	-	41	6
Lampassas	-	35	3
Laredo	3,8	--	39
Liberty	-	44	3
Livingston	-	42	2
Littlefield	-	39	4
Longview	-	30	14
Lubbock	11,13	33,35	32
Lufkin	-	35	10
Marfa	-	20,25	4
Marshall	-	37	18
Mexia	-	34	6
McAllen	-	26	12
Midland	-	29	9
Mineola	-	21	3
Mineral Wells	-	42	6
Monahans	4	19	4
Mount Pleasant	-	33	5
Nocogdoches	-	28	8

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T E X A S (CONTD)

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Orange	-	18	7
Odessa	7	21	10
Ozona	-	45	2
Palestine	7	-	12
Paris	-	19	13
Pampa	-	17	19
Pearsall	-	34	3
Pecos	-	27	5
Perryton	-	34	2
Plainview	-	23	8
Presido	-	16	1
Rankin	-	42	0.5
Rio Grande	-	29	3
Robstown	-	27	7
Rock Springs	-	20	1
Rosenberg	-	36	3
Sabinal	-	44	2
Sanderson	-	23	25
San Angelo	2,6	-	26
San Antonio	4,5,7,9,12	-	319
San Benito	-	34	10
San Diego	-	37	3
San Marcos	-	45	6
Shamrock	-	21	3
Sequin	-	41	7
Sherman	-	14	17
Seymour	-	34	3
Sierra Blanca	-	32	1
Snyder	-	22	4
Sonora	-	15	3
Spur	-	44	2
Stanford	-	20,40	5
Stephenville	-	29	5
Sterling City	-	16	1
Sulphur Spring	-	26	7
Sweetwater	12	14,32	10
Taylor	-	23	8
Temple	-	37	15
Terrell	-	38	19
Texarkana (see Arkansas)			
Tyler	-	45	28
Uvalde	-	14	7
Van Horn	-	18	1
Vernon	-	38	9
Victoria	-	18	12
Waco	-	16,18	71
Waxahachie	-	31	9
Wichita Falls	3,6	--	45
Weslaco	-	42	7

PROPOSED

U T A H

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Beaver	-	19	2
Brigham	-	42	6
Castle Dale	-	14	1
Cedar City	5	17	5
Duchesne	-	31	1
Ephraim	-	28	2
Escalante	-	25	1
Fillmore	-	37	2
Green River	-	43	0.5
Heber	-	16	3
Hurricane	-	21	2
Hyrum	-	20	2
Kanab	-	44	1
Lehi	-	44	3
Loa	-	45	0.4
Logan	-	[illegible],32	12
Milford	-	[illegible]	1
Moab	-	20	1
Monticello	-	23	0.7
Nephi	-	18	3
Ogden	12	34,38,40	44
Panquitch	-	42	2
Parowan	-	15	1
Price	11,13	-	5
Provo	-	21,24	18
Richfield	-	22	4
St. George	-	38	4
Salina	-	35	2
Salt Lake City	2,4,5,7,9	-	204
Tooele	-	27	5
Vernal	-	33	2

PROPOSED

VERMONT

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Brattleboro	-	18	10
Burlington	-	15,17	28
Montpelier	3	20,22	8
Newport	-	38	5
Rutland	-	37	17
St. Albans	-	24	8

VIRGINIA

Charlottesville	-	32	19
Covington	-	29	6
Danville	-	37	33
Emporia	-	27	3
Fredericksburg	-	41,45	10
Harrisonburg	-	36	8
Lexington	-	42	4
Lynchburg	-	14,16	51
Martinsville	-	31	10
Norfolk-Portsmouth-Newport News	4,10,12	25,29	191
Norton	-	32	4
Petersburg	-	21	31
Pulaski	-	39	9
Richmond	3,6,8	15,17,19	~~193~~
Roanoke	7,10	20,22	69
Staunton	-	34	13
Suffolk	-	23	11
Waynesboro	-	38	7
Winchester	-	25	12

PROPOSED

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WASHINGTON

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Aberdeen	-	22	19
Bellingham	-	21,23	29
Bremerton	-	39,41	15
Centralia	-	24	7
Chehalis	-	28	5
Colville	-	45	2
Colfax	-	28	3
Ellensburg	-	42	6
Ephrata	-	17	1
Everett	-	43,45	30
Goldendale	-	29	2
Grand Coulee	-	27	4
Kennewick	-	26	2
Longview	-	40	12
Metaline Falls	-	29	0.5
Moses Lake	-	44	0.3
Mt. Vernon	-	[illegible]	4
Olympia	-	[illegible]	13
Omak	-	[illegible]	3
Oroville	-	32	1
Pasco	-	19	4
Port Angeles	-	32,34	9
Pullman	-	30	4
Puyallup	-	20	8
Republic	-	40	.9
Ritzville	-	23	2
Seattle	4,5,7,11	14,16	453
Shelton	-	30	4
Spokane	2,4,5,7	-	141
Sunnyside	-	15	2
Tacoma	9,13	-	156
Vancouver	-	38	19
Walla Walla	6,8,10	38	18
Waterville	-	35	0.9
Wenatchee	-	37	12
Yakima	-	31,33	27

PROPOSED

WEST VIRGINIA

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Beckley	4	-	13
Bluefield	-	15	21
Clarksburg	-	17	31
Charleston	8,12	30,40	68
Elkins	-	23	8
Fairmont	-	31	23
Hinton	-	24	6
Huntington - Ashland	5	25	79
Martinsburg	-	27	15
Montgomery	-	34	3
Parkersburg	-	43,45	30
Sutton	-	33	1
Weston	-	19	8
Wheeling	7	28,41	61

PROPOSED

WISCONSIN

Antigo	-	22	9
Appleton	-	28	28
Ashland	-	42	11
Beloit	-	18	25
Eau Clair	-	27,29	31
Fond du Lac	-	21	27
Green Bay	-	40,42	46
Hayward	-	36	6
Janesville	-	39	23
Kenosha-Racine	-	32,34;36	116
Ladysmith	-	45	4
La Crosse	-	41,43	43
Madison	-	14,23,25	67
Marshfield	-	35	10
Medford	-	15	2
Merrill	-	19	9
Milwaukee	3,6,8,10	-	587
Praire du Chien	-	30	4
Rice Lake	-	23	6
Rhinelander	-	39	9
Oshkosh	-	16,31	39
Shawano	-	44	6
Sheboygan	-	38	41
Sparta	-	17	6
Stevens Point	-	24,26	16
Superior-Duluth	3,6,8,10,12	-	136
Whitehall	-	20	1
Warsau	-	37	27
Wisconsin Rapids	-	33	11

W Y O M I N G

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Basin	-	38	1
Buffalo	-	22	2
Casper	3,6,8	24	18
Cheyenne	11,13	14,16	28
Cody	-	23,25	3
Douglas	-	36	2
Evanston	-	36	4
Gillette	-	40	2
Green River	-	41	3
Hanna	-	15	1
Jackson	-	44	1
Kemmerer	-	23	2
Lander	-	16	3
Laramie	-	19,21	11
Lusk	-	26	2
Midwest	-	32,34	1
Newcastle	-	27	2
Pinedale	-	14	0.6
Powell	-	27	2
Rawlins	-	17	6
Rock Springs	-	25	10
Riverton	10	18,20	3
Sheridan	9,12,13	15,17	11
Sudance	-	25	0.7
Superior	-	29	1
Thermopolis	-	45	2
Torington	-	44	2
Wheatland	-	28,30	2
Worland	-	31,33	3

PROPOSED

U. S. TERRITORIES

A L A S K A

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Anchorage	2,7,11,13	-	3
Fairbanks	2,4,7,9,11,13	-	3
Juneau	3,8,10	-	6
Ketchikan	2,4,9	-	5
Seward	4,9	-	1

P U E R T O   R I C O

San Juan	7,9,11,13	-	169
Mayaguez	2,4	-	50

PROPOSED

V I R G I N   I S L A N D S

	3	-	25

H A W A I I A N   I S L A N D S

Lihue, Kauai	3,8,10,12	-	4
Honolulu, Oahu	2,4,7,9,11,13	-	179
Wailuku, Maui	3,8,10,12	-	7
Hilo, Hawaii	2,4,7,9,11,13	-	23

APPENDIX D

As pointed out in paragraph 6 of the Notice of Further Proposed Rule Making, the channel allocations for Canada, Mexico, and Cuba, are set forth only for illustrative purposes and to show the effect on the proposed United States Allocation Table of assignments which might be made in Canada, Mexico and Cuba.

CANADA

A L B E R T A

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Calgary	2,4,10,12	14,16,18,27	80
Lacombe	8	29	2
Lethbridge	7	20,24	15
Medicine Hat	5	15,17	11
Red Deer	-	25	3

PROPOSED

B R I T I S H   C O L U M B I A

Chilliwack	12	38	4
Cranbrook	-	17	3
Fernie	-	21	3
Kamloops	4	42	5
Kelowna	13	36	5
Nelson	6	38	6
Penticton	-	18	5
Port Alberni	-	42	5
Prince Rupert	3,7	-	-
Trail	11	14	9
Vancouver-New Westminster	6,8,10	15,17,29,40,44	297
Vernon	2	42	5
Victoria	2	27,36	44

M A N I T O B A

Brandon	5,9,11	37,40	17
Portage la Prairie	-	14	-
Winnipeg - St. Boniface	3,6,7,13	16,18,34,36,38	222

NEW BRUNSWICK

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Cambellton	12	18	7
Edmundston	10	37	7
Fredericton	9	20	10
Moncton	0	17	23
New Castle	0	38	4
St. John	4,6	26,28	52
St. Stephen	0	22	3
Sackville	8	19	2
Woodstock	0	40	4

NOVA SCOTIA

Amherst	0	36	9
Antigonish	9	16	2
Bridgewater	10	33	3
Halifax	3,5,12	27,29,31,39	70
Kentville	0	[illegible]	4
Sydner	0	18,20	28
Truro	0	25	10
Windsor	0	23	3
Yarmouth	13	24	8

PROPOSED

O N T A R I O

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Belleville	0	28	16
Brantford-Simcoe	0	20	38
Brockville	0	45	11
Chatham	0	19	17
Cornwall	0	36	14
Fort Frances	5	28	6
Guelph-Kitchener-Galt	0	37	74
Haileybury	0	21	2
Hamilton	6	29,15	166
Kenora	9	19	8
Kingston	0	26	30
Kirkland Lake	3	16	20
London-St. Thomas	10	35	95
North Bay	2	27	16
Oshawa	0	24	29
Orillia Junction	3	14	20
Ottawa-Hull	7,9,11	14,16	155
Owen Sound	8	30	14
Pembrooke	4	31	11
Peterborough	0	38	25
Port Arthur-Fort William	2,4	19,22,24	24
St. Catherine-Niagara Falls	0	34	51
Sarnia	0	44	19
Sault Ste, Marie	2,12	22	26
Stratford	0	23	17
Sudbury	5,7	23,25	32
Timmons	6	19	29
Toronto	9,11,13	42,40	667
Windsor	9	31,41	105
Wingham	0	33	2
Woodstock	0	26	12

PROPOSED

P R I N C E   E D W A R D   I S L A N D

Charlottetown	13	14	15
Summerside	11	21	5

-4-

QUEBEC

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Amos	0	20	3
Chicoutimi	2,12	20	16
Granby	0	27	14
Hull Ottawa	0	14,16	33
Jonquiere	0	22	14
Matane	0	14	5
Montreal	2,5,8,10,12	42,44	903
New Carlisle	2	16	0
Quebec	4,6,7,9,11	14,16	151
Riviere duLoup	5	26	9
Rimouski	3	23	7
Roberval	0	27	3
Rouyn	0	14	4
St. Hyacinthe-Drummondville	0	29	18
Ste. Anne de la Pocatiere	13	24	1
Shawinigan Falls	0	25	20
Sherbrooke	0	43,45	36
Sorel	0	[illegible]	12
Three Rivers	0	23	42
Val d' Or	0	18	0

PROPOSED

SASKATCHEWAN

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Moose Jaw	4,7	14,16	21
North Battleford	12	22	5
Prince Albert	0	25	13
Regina	2,5,9	21,24,26,35	58
Saskatoon	6,8	15,20	43
Swift Current	0	28	16
Waterous	11	18	1
Yorkton	12	17	6

M E X I C O

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
BAJA CALIFORNIA			
Tijuana	10,12		
Mexicali	11,7		
SONORA			
Nogales	13		
Hermosillo	2		
Ciudad Obregon	3		
Navojo	5		
CHIHUAHUA			
Chihuahua	2		
Hidalgo del Parral	3		
Juarez	11,13		
COAHUILA			
Monclova	5		
Saltillo	4		
NUEVO LEON			
Monterrey	2,6,10,12		
TAMPAULIPAS			
Nuevo Laredo	11,13		
Matamoros	7		

PROPOSED

C U B A

	VHF Channel No.	UHF Channel No.	Pop. in Thousands
Havana) Matanzas)Provinces Las Villas)	3,6,7,9,11,13		

SEPARATE VIEWS OF COMMISSIONER HENNOCK
To Notice of Further Proposed Rule Making (FCC 49-948)

I believe that this Notice of Proposed Rule Making should include a provision for the reservation of a specified number of frequencies in the ultra-high frequency band for the establishment of a non-commercial educational television service. I do not believe it sufficient merely to invite suggestions regarding the possibility of making provision for such a service. For I think that our duty to "encourage the larger and more effective use of radio in the public interest" requires us to make an affirmative effort to make provision to insure that educators will be able to make full use of television, and to enter into the field before the spectrum becomes too crowded.

The rich opportunities afforded educators by television, especially with the growth of knowledge about the efficacy of visual education, should be obvious to all, especially in view of the outstanding results achieved by widespread use of visual education in the armed forces during the last war. It would, I think, result in tragic waste from the standpoint of the public interest if, at the outset of development in this field, adequate provision were not made for the realization of the almost limitless possibilities of television as a medium of visual education. Moreover, the present lack in many places of sufficient qualified teaching personnel makes television available as a vital force in achieving a raising of our educational standards.

I am not unaware of the substantial problem presented by the size of the investment presently required for the establishment of television stations. But this type of difficulty is one which has often been faced and overcome in this nation's history, and I am sure that with sufficient imagination and co-operation on the part of the broadcasting industry, the educational community, and other interested public service groups, and with encouragement by the FCC it will prove to be no lasting obstacle. I therefore believe that, from the outset, the Commission must take a vigorous and affirmative lead in ensuring that this great opportunity is fully realized.

PROPOSED

[fols. 107-108] EXHIBIT "B" TO COMPLAINT

54312-9/50
FCC 50-1064

FEDERAL COMMUNICATIONS COMMISSION
Washington 25, D. C.

In the Matters of

Docket Nos. 8736 and 8975

Amendment of Section 3.606 of the Commission's Rules and Regulations

Docket No. 9175

Amendment of the Commission's Rules, Regulations, and Engineering Standards Concerning the Television Broadcast Service

Docket No. 8976

Utilization of Frequencies in the Band 470 to 890 Mcs. for Television Broadcasting

First Report of Commission
(Color Television Issues)

By the Commission: Commissioners Hyde and Hennock writing separate views and Commissioner Jones dissenting in part.

Adopted: September 1, 1950.
Released: September 1, 1950.

[fol. 109] Table of Contents

[fol. 111] FEDERAL COMMUNICATIONS COMMISSION
Washington 25, D. C.

54312-8/50
FCC 50-1064

In the Matters of

Docket Nos. 8736 and 8975

Amendment of Section 3.606 of the Commission's Rules and Regulations

Docket No. 9175

Amendment of the Commission's Rules, Regulations, and Engineering Standards Concerning the Television Broadcast Service

Docket No. 8976

Utilization of Frequencies in the Band 470 to 890 Mcs. for Television Broadcasting

First Report of Commission
(Color Television Issues)

I. Introductory

This Report deals with the issues relating to color television raised in the above-entitled proceedings. The hearings with respect to these issues were held before the Commission *en banc*, commencing on September 26, 1949 and closing on May 26, 1950. Pursuant to the Commission's Notice of May 10, 1950, the parties were permitted to file Proposed Findings and Conclusions on or before June 26, 1950, and replies thereto by July 10, 1950. Proposed Findings and Conclusions, and Replies were filed by Color Television, Incorporated (CTI), the Columbia Broadcasting System, Inc. (CBS), and the Radio Corporation of America (RCA). Paramount Television Productions, Inc. and Chromatic Television Laboratories, Inc., jointly filed Proposed Findings and Conclusions and a Reply as *amicus* pursuant to the Commission's letter of May 31, 1950.

A. *General Description of Proceedings*

1. These proceedings include not only the issues relating to color television but comprehend a general study and re-

view of the existing commercial television service which occupies 12 channels in the frequency band 54 Mcs. to 216 Mcs. (the Very High Frequency Band, or VHF) and a review of the status of television experimentation and development in the experimental frequency band 470 to 890 Mcs. (the Ultra High Frequency Band, or UHF) with a view to opening this portion of the spectrum for regular television operations. The existing television service is [fol. 112] based on rules and regulations, engineering standards, and a table of channel allocations adopted by the Commission in 1945. Since that time the commercial television service has expanded rapidly from 6 stations on the air in 4 cities, to 106 stations rendering television program service in 65 cities. Since that time, also, over 30 experimental operations have been conducted in the UHF band.

2. The current hearings had their inception in two proceedings instituted by the Commission on May 5, 1948. The first proceeding (Dockets 8736 and 8975) was initiated by the Commission's Notice of Proposed Rule Making of May 5, 1948 (FCC 48-1569).[1] This Notice related to the 12 VHF channels and proposed an amendment of the television allocation table to provide a redistribution of the 12 VHF television channels to the various cities and communities throughout the United States. In general, the 1945 allocation table provided assignments for the 140 metropolitan districts; the Notice of Proposed Rule Making proposed to make additional assignments in some of these metropolitan districts and to provide assignments for some communities not previously covered. During the hearings held in this matter in June and July, 1948, evidence was adduced concerning tropospheric and other types of interference which made it appear probable that the mileage separations provided between co-channel and adjacent channel stations in the existing allocation table and in the Commission's proposed amendments, were not sufficient to permit stations in many areas to provide interference-free service to a

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[1] Docket 8736 was instituted by Notice of Proposed Rule Making issued January 20, 1948 (FCC 48-126) proposing to amend the television allocation table to carry out a tentative agreement with Canada with respect to border allocations. Docket 8736 was consolidated with Docket 8975 on May 5, 1948.

reasonably large area. As a result, the Commission, after a public conference on September 13 and 14, 1948 on the subject, adopted its so-called freeze order of September 29, 1948 (FCC 48-2182) under which television applications were placed in the pending file to await the outcome of the current hearings. This was done in order to give the Commission the flexibility required to carry into effect the lessons to be learned from the forthcoming proceedings. It would obviously have served no useful purpose to have conducted these proceedings if the Commission in the meantime had continued to license television stations in accordance with the old standards, for any change in allocations which would be indicated by the proceedings could be carried out only at the price of excessive dislocation to existing operations.

3. The second proceeding instituted by the Commission on May 5, 1948 (Docket 8976) was intended primarily to obtain the fullest informationn available in the present state of the television art upon the development of transmitting and receiving equipment for use in the UHF band (470 to 890 Mcs.), for either monochrome or color television, and to consider any proposals for the utilization of this band for commercial television broadcasting.[2] The initial hear- [fol. 113] ing on this phase of the proceedings was held September 20 to 23, 1948. It was the consensus of those industry experts who testified at this hearing that color television was not yet ready for commercialization.

4. The scope of the proceedings as set forth in the Notice of Proposed Rule Making and the Order, adopted May 5, 1948, was enlarged by a Notice of Further Proposed Rule Making (FCC 48-2256), adopted October 14, 1948, entitled "Amendment of the Commission's Rules, Regulations and Engineering Standards Concerning the Television and Frequency Modulation Broadcasting Services"

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[2] Docket 8976 was instituted by the Commission's order of May 5, 1948 (FCC 48-1570 which dealt with the frequency band 475 to 890 Mcs. However, the Commission's order of May 25, 1949 (FCC 49-729) added Issue 5 with respect to whether the band 470-500 Mcs. should be allocated to multichannel broad band common carrier mobile radio operation, and revised the caption of the proceedings to include 470 to 890 Mcs.

(Docket 9175). This notice set up a series of engineering conferences for the purpose of undertaking a general review of the rules, regulations and engineering standards in the VHF television service.

5. On November 30 to December 3, 1948, the Commission's staff conducted the informal engineering conferences referred to in the preceding paragraph. At this conference, an *Ad Hoc* Committee was appointed composed of engineering experts from the Commission, other government agencies, and the industry, for the purpose of studying VHF propagation factors. This Committee, after six months of study, submitted a report to the Commission shortly before June 8, 1949. The data and conclusions in the *Ad Hoc* Committee's Report were utilized by the Commission in instituting the present phase of the television hearings by the issuance on July 11, 1949 of a Notice of Further Proposed Rule Making (FCC 49-948) in which the Commission proposed a substantial revision of the VHF allocation table, as well as other matters discussed in the following paragraph.

6. On July 11, 1949, the Commission issued a comprehensive Notice of Further Proposed Rule Making (FCC 49-948) based upon a study of the previous proceedings to date. In this notice, the Commission proposed an extensive revision of its Rules and Regulations and Standards of Good Engineering Practice relating to separation of stations, service areas of stations and allocation principles. In particular, an extensive revision of the allocation table was proposed, based upon the utilization of the 12 VHF channels and also 42 UHF channels; the Notice proposed that the same standards be utilized on these UHF channels as on the VHF channels. Interested persons were also invited to submit comments concerning the utilization of color television under certain prescribed conditions. Finally, interested persons were given an opportunity to offer comments or evidence on such matters as allocation of frequencies in the band 470-500 Mcs. for multi-channel broad band common carrier mobile radio operation; "polycasting"; "stratovision"; and provision for non-commercial educational television broadcast stations in the UHF. As has previously been indicated this Report deals only with the color phase of these proceedings. Subsequent reports will cover the other phases of these proceedings.

[fol. 114] B. *Prior Consideration of Color Television by the Commission*

7. Before proceeding to a discussion of the color phase of the instant proceedings, a brief history of prior action by the Commission in this field is included as useful background. The question of color television has been before the Commission on several occasions, although it was not until 1946 that a formal proposal for the adoption of standards for commercial operation of a color television system was presented to the Commission. Color television systems were first considered by the Commission in a public hearing on January 27, 1941 when the Commission received evidence concerning the Interim Report of the National Television System Committee (NTSC) covering television standardization in the VHF band (Docket 5806). Panel 1 of the NTSC analyzed five American color television systems, all of which were intended to operate in a 6-megacycle channel.[3] Of particular interest to those proceedings in the CBS System No. 3 which was demonstrated in August, 1940, and utilized 343 lines, 60 frames and 120 fields, with mechanical filter discs or drums at the transmitter and receiver. Panel 1 noted that other color television systems were in existence, but were not analyzed because they were broad band and would not work in a 6-megacycle channel. Of particular interest in this category is the RCA System G which was described as a "three-channel, three color additive system consisting essentially of an independent chain of equipment (RMA standards) for each of the three colors, including a separate kinescope of proper screen color for each, with optical combination of the three images." RCA had demonstrated its system to the Commission in February, 1940.

8. On February 27, 1941, the Commission issued a public notice setting forth alternative standards for both monochrome and color television. The hearing on this proposal was held March 20-24, 1941 (Docket 5806). The Report of

[3] Four of these systems were variations of the CBS system, with differences in lines, frames and type of interlace principally; the fifth was a General Electric 2-color system, using dichromatic filter discs, with the odd lines always —in one color, and the even lines always in another color.

the NTSC submitted to the Commission in that hearing stated as to color television:

"The NTSC believes that, although color television is not at this time ready for commercial standardization, the potential importance of color to the television art requires that—

"(a) A full test of color be permitted and encouraged, and that (b) After successful field test, the early admission of color transmissions on a commercial basis co-existent with monochromatic television be permitted employing the same standards as are herewith submitted except as to lines and frame and field frequencies. The presently favored values for lines, and for frame and field frequencies for such a color system, are, respectively, 375, 60, and 120 * * *".[4]

[fol. 115] On May 3, 1941 the Commission issued its "Report on March 20, 1941 Television Hearing" (Mimeo. 49851). On the same day it released its Order, dated April 30, 1941, in which the first commercial television rules and regulations, and television standards, were adopted. As to color television, the Commission's Report stated:

"The three-color television demonstrated by the Columbia Broadcasting System during the past few months has lifted television broadcasting into a new realm in entertainment possibilities. Color television has been known for years but additional research and development was necessary to bring it out of the laboratory for field tests. The three-color system demonstrated insures a place for some scheme of color transmissions in the development of television broadcasting.

"The NTSC proposals provide that color television be given a six-month field test before standardization and commercialization. The Commission finds this requirement necessary. However, immediate experimental color program transmissions are encouraged.

"The standards proposed by the NTSC provide for most of the improvements held out as readily possible

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[4] The Report of the NTSC recommended for commercial monochrome standards 525 lines, 30 frames, 60 fields, and a 6-megacycle channel.

a year ago for monochrome transmissions (black and white pictures). These standards fix the line and frame frequencies at 525 and 30, respectively. The 525 lines provide for greater detail in the pictures transmitted than the 441 lines advocated a year ago. They give substantially equal resolution and more fully exploit the possibilities of the frequency bands allocated for television. Different line and frame frequencies will likely be required for color transmissions. This, however, is a matter for future consideration after color transmissions have been adequately field tested. * * *

"The Commission is requesting the industry to provide the necessary test data as to both color transmissions and synchronizing signals within the six-month period following the beginning of commercial operation."

9. The Commission's Order adopted transmission standards for monochrome—525 lines, 30 frames, and 60 fields—with the following footnote:

"The presently favored values for lines and for frame and field frequencies for experimentally field testing color transmissions are, respectively 375, 60 and 120;"

and further provided that "on or before January 1, 1942, the licensees of television broadcast stations shall submit to the Commission complete comparative test data on color transmissions, with recommendations as to standards that may be adopted by the Commission for color television."

[fol. 116] 10. At a public hearing before the Commission, held on April 9, 1942 (Docket 5806), NTSC testified that it had submitted a report on color television to the Commission; and that it was felt that the demands of the national emergency had prevented the industry's proceeding with color television experimentation to the extent that would have been possible in normal times and as a result definitive conclusions could not be presented.

11. Testimony on color television was again presented to the Commission in the 1944-1945 general allocation proceeding (Docket 6351). In that hearing, which was held

from September 28 to November 2, 1944, the Radio Technical Planning Board (RTPB) recommended to the Commission that "adequate standards for color television for a six-megacycle channel cannot be established at this time" but stated that, "this action was taken without prejudice to the continuation of experimentation in color television in such channels." It further recommended that:

"Provision should be made at this time for higher frequency channels in which experimentation and development may be conducted looking toward an improved service which may include color, higher definition and any other improvements which may occur. It is recommended that the channels be twenty megacycles wide, but that no other standards be established for them at this time."

12. In the 1944-1945 hearing, witnesses for CBS discussed the utilization of the UHF band for high definition monochrome and color television, and stated that their experimentation looked toward widening of the present 4-megacycle video band to 10 megacycles, requiring a total channel width of 16 megacycles, to be utilized for 735-line monochrome transmissions and 525-line color transmissions. An RCA witness took the position that "the primary purpose of going to higher frequencies and wider bands should be to obtain adequate color television with at least as much detail as now obtained in black and white."

13. The Proposed Report of the Commission, issued January 15, 1945, and the Final Report of the Commission, issued May 25, 1945 in Docket 6651, in general, reaffirmed the standards for monochrome in the VHF band. The UHF band was allocated to television experimentation for the purpose of developing color television and high definition monochrome television. The Final Report contained the following statement concerning the UHF band:

[fol. 117] "As was pointed out in the proposed report, the Commission is still of the opinion that there is insufficient spectrum space available below 300 megacycles to make possible a truly nation-wide and competitive television system. Such a system, if it is to be developed, must find its lodging higher up in the spectrum where more space exists and where color pictures and superior monochrome pictures can be de-

veloped through the use of wider channels. In order to make possible this development of television, the Commission has made available the space between 480 and 920 megacycles for experimental television. The time which may elapse before a system can be developed to operate on wider channels on these ultra-high frequencies is primarily dependent upon the resourcefulness of the industry in solving the technical problems that will be encountered. In this portion of the spectrum it is contemplated that the Commission will license the entire band between 480 and 920 megacycles for experimental television and will not designate any particular channels. Applicants desiring to operate in this portion of the spectrum should consult with the Chief Engineer as to the exact frequency band they should utilize.

"The Commission repeats the hope expressed in its proposed report that all persons interested in the future of television will undertake comprehensive and adequate experimentation in the upper portion of the spectrum. The importance of an adequate program of experimentation in this portion of the spectrum cannot be over-emphasized, for it is obvious from the allocations which the Commission is making for television below 300 megacycles that in the present state of the art the development of the upper portion of the spectrum is necessary for the establishment of a truly nation-wide and competitive television system."

14. The Commission was requested for the first time to promulgate commercial standards for color television in a petition filed by CBS on September 27, 1946. The CBS proposal requested the commercialization of color television in the UHF band, using a field sequential system with 525 lines and 144 fields, and utilizing wide band channels of 16 megacycles. The hearing on this proposal was held between December 3, 1946 and February 13, 1947. Demonstrations on the record of the CBS proposed system were held on January 27 and 28, 1947.

15. Although the CBS system was the only one formally proposed to the Commission for adoption, RCA advanced for consideration a simultaneous system, disclosed to the public on October 31, 1946. Testimony was taken concerning this system and demonstration on the record of this

system was held on January 29, 1947. In the RCA simultaneous system each picture was scanned simultaneously in three colors, the three images were transmitted simultaneously on three video channels, and the images were combined optically at the receiver to produce a single color [fol. 118] picture. Each of the three color pictures could have the same number of lines, frames and fields and the same standards as monochrome transmissions. As demonstrated, however, the system used a total channel of 14.5 megacycles, including 4-megacycle video bands for the green and red channels, and a 1.3 video bandwidth for the blue channel. Since the green signal was transmitted on the same standards as monochrome, except for the UHF carrier, the RCA color transmissions could be received on existing monochrome receivers in monochrome, provided a UHF converter was utilized. RCA mentioned the "mixed highs principle" as having "excellent promise of providing still further reduction in band width requirements."

16. As already indicated, RCA did not propose adoption of standards covering its system. Its purpose in disclosing the system was stated by Dr. C. B. Jolliffe, Executive Vice President in Charge of RCA Laboratories, as follows:

> "Again I wish to emphasize that the simultaneous color system is not disclosed at this time for the purpose of requesting adoption of standards for its operation. Under normal circumstances it would not have been publicized until development had progressed to a more advanced stage.
>
> "It has become necessary, however, to describe this system in order to show that a superior system of color television is possible which is compatible with existing monochrome television and which can be adopted later without loss to the public and the broadcasters who have had enough faith in television to invest in the present excellent system.
>
> "The basic principles are established beyond question, although the engineering details are yet to be worked out. This will require some time, as Mr. Kell will explain, but the end result will be an excellent and practical system introduced without penalty to the existing service and without jeopardy to the investment

of public and broadcasters in black-and-white television."

17. The CBS system was supported at the hearing by Zenith Radio Corporation and Cowles Broadcasting Company. Denial of the CBS petition was urged by RTPB Panel 6 (on Television), RMA, RCA, Philco, DuMont and Television Broadcasters Association.

[fol. 119] 18. The "Report of the Commission" (Mimeo. 5466), issued March 18, 1947, denied the CBS petition, saying, in part:

"Before approving proposed standards, the Commission must be satisfied not only that the system proposed will work but also that the system is as good as can be expected within any reasonable time in the foreseeable future. In addition, the system should be capable of permitting incorporation of better performance characteristics without requiring a change in fundamental standards. Otherwise, the danger exists that the standards will be set before fundamental developments have been made with the result that the public would be saddled with an inferior service, if the new changes were not adopted, or if they were adopted, receivers already in the hands of the public would be rendered useless.

"Judged by the foregoing test, the Commission is of the view that the standards for color television proposed by Columbia Broadcasting System should not be adopted. In the Commission's opinion the evidence does not show that they represent the optimum performance which may be expected of a color television system within a reasonable time. The Commission bases this conclusion on two grounds. In the first place, the Commission believes that there has not been adequate field testing of the system for the Commission to be able to proceed with confidence that the system will work adequately in practice. Secondly, the Commission is of the opinion that there may be other systems of transmitting color which offer the possibility of cheaper receivers and narrower band widths that have not yet been fully explored. Both grounds will be discussed in greater detail further on in the report."

19. In its Report, the Commission called for further experimentation in the color television field:

"Two specific problems, in the Commission's opinion, should be carefully examined. In the first place, there should be further experimentation looking towards the development of low cost television receivers. A large portion of the radio spectrum has been allocated to television. The demand for space in the spectrum from other radio services is very keen and it is not possible to satisfy all requests. The objective of television heretofore mentioned of bringing news, education, culture and entertainment to large numbers of people cannot be carried out unless television receivers are manufactured and sold at a price which the average family can afford to pay.

[fol. 120] "Secondly, further experimentation should be conducted along the line of finding methods of transmitting color television over narrower channels. Under the Columbia proposals, each television channel would be 16 megacycles wide. That means that the band 480 to 920 megacycles would accommodate but 27 channels. It was the Commission's hope in allocating the band 480 to 920 megacycles for television that in this band it would be possible to provide for a truly nationwide competitive television system. The evidence before the Commission shows that 27 channels may not ultimately be enough to provide for a truly nation-wide competitive television system. Every effort must, therefore, be made to narrow the band width required for color television. It should be emphasized that narrowing the band width should not be at the expense of picture brightness, picture detail, color fidelity, or other features of television performance. The objective should be a narrower band width while retaining and even improving the quality of television performance.

"At the hearing there was much testimony concerning the desirability of a system which would permit present television receivers, simply by adding a converter, to receive in monochrome, the broadcasts of stations broadcasting color programs in the 480 to 920 megacycle band. This so-called principle of compatibility, it is urged, will encourage manufacturers

of black and white equipment to proceed at full pace, will enable the public to buy receivers with confidence that they will not be rendered obsolete, and will not impede the development of color television. The Commission is of the opinion that compatibility is an element to be considered, but that of greater importance, if a choice must be made, is the development of the best possible system, employing the narrowest possible band width, and which makes possible receivers capable of good performance at a reasonable price.

"The Commission is of the opinion for the reasons which have been discussed that the petition of Columbia Broadcasting System should be denied. In reaching this decision, the Commission does not desire to minimize in any way the advances that have been made in the development of color television. On the contrary, the Commission is of the opinion that Columbia Broadcasting System, Dr. Goldmark and the people who have worked under him are to be commended for their continuing interest in the field and for the great strides they have made in this field in so short a period. The Commission, however, cannot escape the conclusion that many of the fundamentals of a color television system have not been adequately field tested and that need exists for further experimentation along the lines noted above. It is hoped that all persons with a true interest in the future of color television will continue their experimentation in this field in the hope that a satisfactory system can be developed and demonstrated at the earliest possible date."

[fol. 121] 20. Color television was again explored by the Commission in the hearings held in these proceedings on September 20 to 23, 1948, when the state of the television art in the UHF band was considered (Docket 8976). The Commission's order instituting this hearing contained the following issues:

"3. To obtain full information concerning the state of development of transmitting and receiving equipment for either monochrome or color television broadcasting, or both, capable of operating in the band 475 to 890 Mc.

"4. To obtain full information concerning any proposals for the utilization of the band 475 to 890 Mc.,

or any part thereof, for television broadcasting and the standards to be proposed therefor."

21. In the September 20, 1948, UHF hearing, the Joint Technical Advisory Committee (JTAC), sponsored by the Radio Manufacturers Association and the Institute of Radio Engineers, presented a report on the "Utilization of Ultra-High Frequencies for Television" and submitted the following conclusion as to UHF color television:

"Item 3 of the issues and questions before this hearing * * * states that information is requested on the use of ultra-high frequencies for color television. The JTAC reports that no proposals for standards for commercial operation of a color television system have been made to it. A letter from Mr. Adrian Murphy (Annex 16) outlines but does not propose two color television systems.[5] The JTAC is of the opinion, based on evidence submitted to it by various subcommittees of the RMA and IRE, that it is impracticable to set up commercial standards for color television in the present state of the art.

"The fact remains that even though the ultimate color service cannot be specified at this time, nothing should now be done that would prevent a later allocation of color channels. It is important, therefore, to consider the effect of an interim allocation of UHF channels to a 6-megacycle monochrome service on the eventual establishment of a color service.

"If such interim 6-megacycle allocations are to be made, and if such channels are later to be converted to a color service, it is important to consider the bandwidth relationships of the two services.

* * * * * * *

[fol. 122] "In view of these facts (i.e., the difficulties in converting 6-megacycle UHF monochrome to wider band UHF color), the JTAC comes to the conclusion that it will be difficult, both in theory and practice, to provide for a conversion from UHF monochrome assignments to UHF color assignments. The JTAC believes, therefore, that any assignment of monochrome

[5] Mr. Murphy is a CBS vice-president.

service to UHF channels would represent a permanent removal of the space so occupied from that available for any other service."

C. *Color Phase of Instant Proceedings*

22. As mentioned above, the color phase of the instant proceedings was instituted by the Commission's Notice of Further Proposed Rule Making (49-948), issued July 11, 1949. While in this notice the Commission did not propose specific amendments to its rules and standards looking toward the commercialization of color television, in Appendix A to the Notice the Commission described the conditions upon which it would consider proposals for a change in transmission standards on Channel 2 through 55 looking toward the establishment of color television. Paragraphs II-B and C of Appendix A stated in this connection:

"B. The Commission will give consideration to proposals for a change in Transmission Standards on channels 2 through 55 looking toward color television or other television systems. Any such proposal shall:

1. Be specific as to any change or changes in the Transmission Standards proposed; and
2. Shall contain a showing as to the changes or modifications in existing receivers which would be required in order to enable them to receive programs transmitted in accordance with the new standards.

"C. It is proposed to consider changes in Transmission Standards for Channels 2 through 55 only upon a showing in these proceedings that:

1. Such system can operate in a 6-megacycle channel; and
2. Existing television receivers designed to receive television programs transmitted in accordance with present transmission standards will be able to receive television programs transmitted in accordance with the proposed new standards simply by making relatively minor modifications in such existing receivers."

[fol. 123] 23. Pursuant to the above notice, comments relating in whole or in part to color television were filed by

the Joint Technical Advisory Committee (JTAC); the Radio Manufacturers Association;[6] the Radio Corporation of America; the Columbia Broadcasting System, Inc.; Color Television, Incorporated; Charles Willard Geer; Leon Rubenstein; Philco Corporation; and Allen B. DuMont Laboratories, Inc. Webster-Chicago Corporation and American Television, Inc., also were made parties to the hearing upon their request. Celomat Corporation was permitted to testify in the hearing on its own behalf. CBS, CTI and RCA were the only parties who appeared as proponents of their own color television systems. The technical characteristics and performance of these three color television systems will be described hereafter.

24. The hearing on the color issues was held before the Commission *en banc* commencing September 26, 1949 and ending May 26, 1950—a total of 62 hearing days, covering 9,717 pages of transcript. The hearing was held in two phases, the first of which ended on November 22, 1949, at which time the hearing was continued to February 6, 1950.[7] The second phase commenced on February 20, 1950 and ended May 26, 1950. During the intervening period, the parties conducted field tests of color television systems pursuant to the Commission's "Notice Concerning Field Test Programs and Further Testimony", adopted November 21, 1949 (FCC 49-1547). The hearings were held in Washington, D. C., except for the second comparative demonstrations of CBS, RCA and CTI color television systems which were held on February 23, 1950 at the Commission's Laboratories at Laurel, Maryland; the CBS demonstration of horizontal interlace held on April 26, 1950 at the CBS Laboratories in New York City; and the CTI demonstration held on May 17, 1950 at San Francisco, California. In all, 53 witnesses testified and 265 exhibits were offered. A list of the witnesses and a description of the exhibits are attached as Appendices A and B.

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[6] Radio Manufacturers Association has changed its name to Radio and Television Manufacturers Association.

[7] On motion of certain parties, the CTI demonstration was extended from February 6 to February 20, 1950, and the second comparative demonstration was extended from February 8 to February 23, 1950 (See Commission's Order Extending Date of Second Comparative Demonstration, adopted December 8, 1949, FCC 49-1622).

25. During the course of the hearing, the following demonstrations were conducted on the record of the proceedings:

(a) On October 6 and 7, 1949, CBS demonstrated its color system at the Carlton Hotel, Washington, D. C.

(b) On October 10, 1949, RCA demonstrated its color system at the Washington Hotel and the Wardman Park Hotel, Washington, D. C.

(c) On November 21 and 22, 1949, a comparative demonstration was conducted at Temporary "E" Building, Washington, D. C., showing the operation of the CBS color system, the RCA color system, and conventional DuMont monochrome television receivers. At this demonstration, the Commission demonstrated a conventional Bendix television receiver equipped with the automatic adapter invented by members of the Commission's staff.

[fol. 124] (d) On February 20, 1950, CTI demonstrated its color system at the Statler Hotel, Washington, D. C.

(e) On February 23, 1950, a second comparative demonstration was conducted showing the operation of the CBS color system, the RCA color system, and the CTI color system, at the Commission's Laboratories at Laurel, Maryland.

(f) On April 6, 1950, RCA demonstrated its trichromatic (three-color) receiving tubes at the Trans-Lux Building, Washington, D. C.

(g) On April 26, 1950, CBS demonstrated its horizontal interlace at the CBS Laboratories in New York City.

(h) On May 17, 1950, CTI demonstrated its color system at the St. Francis Hotel, San Francisco, California.

[fol. 125] II. Description of the Three Systems.

A. *General*

26. In order better to understand the technical operation of the three color systems which have been proposed in these proceedings, it is useful to have a brief general description of how the present monochrome television system works and a discussion of some of the fundamental aspects of color television which are common to all three systems.

It should be noted that many of the technical features of television systems are not capable of accurate description except in very technical terms or complicated formulae; these would not be intelligible to other than scientists or engineers. In order to make this Report as useful and understandable as possible to the public and interested persons with no specialized training, we have simplified the description considerably and have attempted to compare the operation of television systems to well-known techniques in the interest of understandability. This method, of course, does not have the precise accuracy of the more technical description but it will aid in understanding the technical problems involved. Those interested in the more technical aspects of the systems will find such material in the record.

27. A television picture originates in the television camera where an electron beam scans an image of the scene to be transmitted in a series of lines from left to right and top to bottom. The electron beam in the process of scanning generates signals which vary in amplitude in proportion to the relative lightness or darkness of the area in question. As the scanning beam reaches the right hand end of each line, it snaps back to the left hand of the scene and scans another line. This process is repeated until the scene has been scanned from top to bottom. At this point the scanning beam snaps back to the left hand top of the picture and starts the scanning process all over again.

28. From the above, it might appear that the lines are scanned consecutively; and, indeed, in the early experimental days of television this was done. However, it was soon discovered—and this was one of the fundamental developments in early television—that certain advantages could be gained at the expense of only relatively minor disadvantages by scanning alternate lines.[8] Thus, the electron beam scans line 1, skips a line, scans line 3, skips another line, scans line 5, and so on to the bottom of the picture, scanning only the odd lines. The electron beam then snaps back to the top of the picture and scans all the even lines. This process is known as "line interlace" or "vertical interlace."

[8] The explanation for this is set forth in Paragraph 32, below.

29. At the receiver the process set forth above is repeated. The signals which have been generated by the scanning beam at the camera are received on an antenna connected with the receiver. At the receiver there is also an electron beam which operates in the same fashion as and in step with the one in the camera. The light and dark portions of each line are reproduced on the face of the tube to correspond to the original scene by the action of the electron beam in varying the amount of light generated on the face of the tube in proportion to the amplitude of each signal as generated at the camera.

[fol. 126] 30. In the preceding paragraph, mention was made of the fact that the electron beam at the receiver is in step with the scanning beam at the camera; this is indispensable if a picture is to be achieved. This result is accomplished by means of synchronizing pulses which are generated at the station by means of a synchronizing generator and are transmitted along with the signals already referred to. For the purposes of this description there are horizontal synchronizing pulses and vertical synchronizing pulses. The horizontal synchronizing pulse comes at the beginning of each line. Its function is to make sure that the electron beam snaps back to the position on the left at the correct time. The vertical synchronizing pulse comes at the beginning of each field—i.e. each time the electron beam has scanned from the top of the scene to the bottom—and is designed to assure that the electron beam will snap back to the position at the top of the picture at the appropriate time. During the time that the electron beam is in the process of being snapped back at the end of each line or field, appropriate blanking pulses are transmitted which are designed to black out the electron beam in order to obscure the retrace of the scanning beam.

31. Television reproduction is somewhat similar to the operation of motion pictures. In motion pictures a rapid succession of still pictures is projected on the screen. If the pictures are projected rapidly enough, the eye through the persistence of vision, sees the result as an uninterrupted image. In television, the process also makes use of the persistence of vision in a similar fashion except that the individual pictures are formed by a rapidly moving electron beam instead of the entire scene being shown at once.

32. There remains for discussion the ascertainment of

the number of lines and number of fields per second in the present television system. A system should have a sufficient number of lines to portray the finer vertical detail in the picture. A sufficient number of fields per second is desirable for two reasons. In the first place, in order to have smoothness of motion portrayed, the fields must succeed each other at a rapid rate. If the rate is too slow, the motion will be jerky. In the second place, a high field rate is necessary in order to avoid flicker. If the field repetition rate is too low, annoying flicker is apparent unless the picture is very dim. By increasing the field rate, it is possible to have pictures of adequate brightness with no flicker.

[fol. 127] 33. However, fundamental laws of physics must be reckoned with in establishing standards for lines and fields per second. A television station broadcasts on a channel 6 megacycles wide. Under our present standards about 4 megacycles of video information can be utilized for the picture. Within a 4 megacycle band must be accommodated adequate lines for vertical detail, horizontal detail (usually expressed in terms of lines also) and field repetition rate.[10] Any number of combinations of these variables may be utilized within a 4-megacycle band but in choosing a combination, care must be used to make sure that the result is a balanced picture with adequate detail and a sufficient number of fields per second to make possible

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[9] The relation between the field repetition rate and flicker explains the importance of line interlace discussed in Paragraph 28. Experience has shown that so far as large area flicker is concerned, doubling the field rate with interlace is comparable to doubling the frame rate without interlace. Thus, for a given flicker threshold, line interlace requires only one-half of the scanning speed, and thus for a given amount of picture detail requires but one-half as much band width. This makes possible more effective channel utilization.

Flicker can also be reduced by the utilization of tubes with long persistence phosphors as explained in paragraphs 58-60.

[10] In addition, the necessity of allowing time for vertical and horizontal blanking prevents the continuous use of the band width for transmission of picture detail.

smoothness of motion and adequate brightness of pictures without objectionable flicker. The values which the Commission has adopted for black and white television are 525 lines per picture, 30 frames per second, and 60 fields per second. With this combination the horizontal resolution in terms of lines is 380.[11] To express the same result in another manner, the present standards provide for a horizontal synchronizing pulse rate—the number of times per second a horizontal synchronizing pulse is required to snap back the electron scanning beam—of 15,750 (525 x 30) and a vertical synchronizing pulse rate of 60. As has already been stated, any one of the above values can be changed but when this is done a change in one or more of the other values is automatically required if a 4-megacycle band is utilized.

34. Thus far, we have described generally the operation of monochrome television. So far as color television is concerned, in theory it is accomplished in the same way as monochrome television except that each picture is sent three times, once in each of the three primary colors utilized—red, green and blue. These primary components may be transmitted simultaneously, as they are in color movies, or sequentially at a sufficiently rapid rate so that the persistence of vision causes the eye to blend them together. All of the systems proposed in this hearing are sequential systems; the major differences lie in the scanning patterns and the rate at which the primary colors are changed. The larger the area continuously sent in one primary the less rapidly will the color changes occur. The scanning pattern and the color switching rate determine the apparatus requirements and the success of maintaining the illusion of continuity. The Columbia system is a field sequential system, in which the colors are changed between each field 144 times per second, and color pictures are transmitted at a rate of 24 per second. The CTI system is a line sequential system, in which the colors are changed between each scanning line at a rate of 15,750 times per

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[11] This is the approximate theoretical capacity of the system, ignoring blanking time. The present standards provide that 82 to 86 percent of the line scanning time may be used for horizontal blanking and 5 to 8 percent of the lines are lost during vertical blanking.

second, and color pictures are transmitted at a rate of 10 [fol. 128] per second. The RCA system is a dot sequential system, which involves a color change between elemental picture areas along each scanning line, and a switching rate of about 11 million times per second. Color pictures are transmitted at a rate of 15 per second.

35. It would appear from the foregoing that a video channel three times the width of the monochrome channel would be required for color television. However, by means of certain band-saving devices or by a change in one or more of the factors set forth in Paragraph 33, or by a combination of both methods, each of the proponents has devised a system that is designed to work in a 6-megacycle channel. These processes are described in detail later on in this Report in connection with each of the systems.

B. *The CTI System*

36. It is difficult to make an adequate description of the CTI system because it was frequently changed during the course of the hearing, technical witnesses for CTI were not in complete agreement, and some of the more complicated points were never clearly expounded by CTI. We have, however, endeavored to make as complete and accurate a description as possible.

37. As has already been indicated, the CTI system is a line sequential system. In this system, scanning is at the same rate as in the monochrome system—15,750 lines and 60 fields per second. The system derives its name from the fact that as the scanning of each line is completed, the color is changed. Thus, line 1 is scanned in red, line 3 in green, line 5 in blue, line 7 in red, and so on to the bottom of the picture. This completes a field and the scanning beam snaps back to the top of the picture where the even lines are then scanned in the same fashion. Thus, at the end of the second field, all of the lines have been scanned once, but each line will have been scanned, in but one color. In order for each line to be scanned in each color, it is necessary to change the initiation of the color scanning between fields. Otherwise, in field 3, line 1 would be scanned in red again, line 3 in green, line 5 in blue, and so on. It is thus necessary to provide, for example, that in field 3, line 1 be scanned in green and in field 5, in blue. This change in the initiation of the color scanning insures that

each line is scanned in each of the three primary colors. As a result, it takes six complete fields within which all lines are scanned in all colors. Thus, in this particular system, 10 color pictures are completed each second.

38. If a uniform change in the initiation of color scanning—such as is described in the preceding paragraph—were utilized, a serious line crawl would be apparent across the image. Several sequences of non-uniform shifts were demonstrated by CTI in an effort to minimize line crawl. One of the earlier shifts was called the single shift and resulted in scanning each picture line in only two of the three primary colors. This shift was abandoned by CTI in favor of a double shift. Several variants of the double shift were described by CTI witnesses. The most recent form of double shift and the one presently urged by CTI [fol. 129] was demonstrated in San Francisco on May 17, 1950. It is called the interlaced shift. In this system, the order of scanning is changed from the normal pattern where odd lines are first scanned and then even lines, so that the odd lines are scanned in three successive fields, then the even lines are scanned in three successive fields, and so on. The color sequence scanning is so arranged that adjacent lines are not scanned in the same color in successive fields and the progression of color from line to line is revised at intervals not in excess of three succeeding fields. Ten complete color pictures per second result from the interlaced shift. An additional synchronizing pulse is required during the vertical blanking period for the operation of the color shift.

39. The apparatus with which CTI demonstrated its system may be briefly described as follows: At the transmitting end there is a single camera tube, upon the surface of which the optical system projects three primary color images of the scene, side by side—red, green and blue. The electron beam starts scanning at the left which is in the red area. This portion of the tube responds only to red components and as the electron beam scans through this red portion, it generates signals which vary in amplitude in proportion with the relative intensity of the red components. It takes 1/15,750 of a second to complete line 1—the time required under our present standards for the scanning of one line. At the expiration of this time, the scanning beam enters the green area and since the electron beam scans at a

sloping angle, the beam is now at line 3. This line is scanned in green in 1/15,750 of a second. The scanning beam then enters the blue area at line 5 and scans this in blue in 1/15,750 of a second. The electron beam then snaps back to the left hand side of the picture to scan line 7 in red, and so on until one field is completed in 1/60 of a second. The process is then repeated for successive fields. At the receiver, a similar scanning process is employed in connection with a cathode-ray tube having three vertical bands of color primary phorphors—red, green and blue. A suitable optical system is employed to superimpose the three color images on a viewing screen.

40. All of the synchronizing signals, horizontal and vertical, employed in the case of monochrome are also utilized in the CTI system; there are also additional synchronizing signals discussed above. The CTI color receiver must be so constructed that it does not react to each horizontal synchronizing pulse in the same manner as a monochrome receiver. If it did, the scanning beam would be snapped back to the left hand of the picture when the first pulse is transmitted—at 1/15,750 of a second. However, at that moment the scanning beam has only traversed the first third of the tube's surface—the red portion—and must still [fol. 130] scan across the green and blue surface. Accordingly, appropriate circuits are required to make sure that the scanning beam is snapped back only after every third horizontal pulse. This can be accomplished by appropriate counting circuits or by adding an appropriate pulse during the blanking period of each third horizontal pulse.

C. *The CBS System*

41. In the CBS system scanning is accomplished in the same manner as in the present system. First, all of the odd lines are scanned and then the even lines, and so on. The effect of color is achieved by the fact that when the odd lines are scanned in the first field, they are scanned in red; the even lines of the second field are scanned in blue; the odd lines of the third field are scanned in green; the even lines of the fourth field are scanned in red; the odd lines of the fifth field are scanned in blue; and the even lines of the the sixth field are scanned in green. Thus, it takes six complete fields to produce one complete color picture.

The fact that the color is switched at the end of each field gives the CBS system its name, field sequential system.

42. The CBS system does not utilize the same scanning standards as does monochrome television. Instead of 525 lines the CBS system has 405 lines. The theoretical horizontal resolution in terms of lines is reduced from 380 lines to 205. A field rate of 144 per second is employed instead of 60, and 24 complete pictures per second result rather than 30. Under the CBS system the horizontal synchronizing rate is 29,160 per second[12] as compared with 15,750 per second for black and white, and the vertical synchronizing rate is 144 per second as contrasted with 60 per second for black and white.

43. During the latter stages of the hearing, CBS offered testimony concerning the utilization of horizontal interlace in its system as a means of improving horizontal detail; it did not offer horizontal interlace as a proposal. A dem-[fol. 131] onstration of this process was held on the record in New York City on April 26, 1950. In this system, each line is broken up into picture elements with blank spaces in between. In the first field, alternate dots are sampled for the odd lines; in field two, alternate dots are sampled[13] for the even lines. The blank spaces are filled in by successive fields. It thus takes 12 fields to produce a complete color picture and as a result 12 complete color pictures per second occur. However, even with horizontal interlace, color switching in the CBS system occurs after each field, the horizontal interlace being used to increase the horizontal resolution.

44. The apparatus utilized by CBS to demonstrate its system can be described as follows: At the camera a rotating disc containing segments of red, blue and green filters is inserted between the lense and the tube. The disc rotation is coordinated with the field scanning rate of 144 per second. In the 1/144 of a second that the red filter is in

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[12] This figure is derived as follows: Each complete picture per second has 405 lines. Each of the 24 complete color pictures is composed of three 405 line pictures made up of red, blue and green components. Thus, 405 x 24 x 3 = 29,160.

[13] A description of sampling is set forth in Paragraph 51 in connection with the RCA system.

front of the tube, all of the odd lines are scanned. Since the filter transmits red components, the scanning beam generates signals that vary in amplitude in proportion to the varying intensity of the red components of the scene being transmitted. The same process is repeated for each field. At the receiver a rotating disc with colored segments is placed in front of the cathode-ray tube. When the receiver is turned on and the motor attains its full speed, the color disc may or may not be in proper step with the disc at the camera. If the colors are false, as indicated by skin tones or other obvious color faults, the viewer presses a button to place the disc in step. This may require one or two pushes of the button. Once the correct color position is attained, the synchronizing pulses automatically keep it correct. The scanning at the receiver repeats the process at the camera end, and a color picture results. At the New York demonstration, CBS also demonstrated a projection receiver somewhat similar to that employed by CTI. In addition, at the Laurel demonstration, it demonstrated a receiver which automatically chose the correct color. This requires an extra synchronizing signal to insure correct color phase.

[fol. 132] D. *The RCA System*

45. It is difficult to make an accurate description of the RCA system because it involves new and complex techniques, many of which were never clearly expounded during the hearing. We have, however, endeavored to make as complete and accurate a description as possible.

46. The RCA system unlike the other two systems involves a change in the scanning method utilized under the present system. As will be recalled, under the present system the electron beam scans a line continuously from left to right, skips a line, scans another line, and so forth until the end of the field. The lines that were not scanned during the first field are then scanned in the second field. This is line interlace and the process is retained in the RCA system. What RCA has done is to add a process called dot interlace. As the name implies, dot interlace is accomplished by scanning each line in a series of dots rather than continuously. As illustrated in the table below, during the first scanning field, the odd numbered lines are scanned in order. Colored dots are laid down in order along line

1 as shown. Next, line 3 is scanned with a displacement for each color dot shown. The remaining odd lines are scanned in order. This scanning of the first field takes place in one-sixtieth of a second.

47. During the second field, the even lines are scanned, first line 2 with the colors laid down as shown, then line 4, and so on. The dot pattern laid down during the third field is shown by the lower diagram where the odd lines are scanned in succession. During the fourth field, the even lines are again scanned in succession with the color dot pattern shown. Thus, the odd lines are scanned during the first field, but dots of the same primary color are separated by spaces. The even lines are scanned during the second field, again with spaces between like color dots. During the third field, the odd lines are again scanned but with the color dots displaced so that the spaces are filled. The even lines are scanned during the fourth field, with the color dots displaced to fill in the spaces left during the second field scanning. Four scanning fields are required to completely cover the picture area, with all spaces filled, with say, green dots. Simultaneously, the area is being covered with red dots and with blue dots. Since there are 60 fields per second, it may be said that there are 15 complete color pictures per second.

[fol. 133]

1st Field

Line												
1	G		R		B		G		R		B	
2												
3		B		G		R		B		G		R
4												
5	G		R		B		G		R		B	
6												

2nd Field

Line												
1												
2		B		G		R		B		G		R
3												
4	G		R		B		G		R		B	
5												
6		B		G		R		B		G		R

3rd Field

Line							
1		B	G	R	B	G	R
2							
3	G	R	B	G	R	B	
4							
5		B	G	R	B	G	R
6							

4th Field

Line							
1							
2	G	R	B	G	R	B	
3							
4		B	G	R	B	G	R
5							
6	G	R	B	G	R	B	

Combining the above lines, dots and fields into one table, we have the following representation of a complete color picture (the numbers in the table refer to fields):

Line	G	B	R	G	B	R	G	B	R	G	B	R
1	1	3	1	3	1	3	1	3	1	3	1	3
2	4	2	4	2	4	2	4	2	4	2	4	2
3	3	1	3	1	3	1	3	1	3	1	3	1
4	2	4	2	4	2	4	2	4	2	4	2	4
5	1	3	1	3	1	3	1	3	1	3	1	3
6	4	2	4	2	4	2	4	2	4	2	4	2

48. Scanning is accomplished in the following manner. The RCA color camera consists of three separate camera tubes each of which is capable of response to 4 megacycles. In front of these tubes is an optical system consisting of dichroic mirrors and lens. The dichroic mirrors are so constructed that each one reflects only one of the three primary colors—green, blue, red. The light reflected by each such mirror falls upon the photosensitive surface of one of the three camera tubes. Each of the camera tubes has applied to it the same horizontal and vertical scanning pulses from a common synchronizing generator. The electron scanning beams in the three tubes thus scan the entire scene simultaneously and generate separate signals. Of course, the signals generated by the scanning beam in the green

tube vary in amplitude in proportion to the relative intensity of the green components of the picture being scanned and similarly for the blue and red cameras.

[fol. 134] 49. Thus, three signals are derived from the camera tubes, each with a response out to four megacycles. Since these signals must be transmitted in a 4-megacycle video band, some method must be devised of combining or merging these signals for purposes of transmission. To understand how this is done, a discussion of the so-called mixed-highs principle is necessary.

50. As was set forth above, each of the three camera tubes in the RCA system is capable of response out to four megacycles. Where a picture being scanned does not have fine detail, the full response of 4 megacycles is not necessary. Coarse detail can be transmitted by a camera with a much narrower response—e.g., 2 megacycles. The response between 2 and 4 megacycles is necessary for fine detail. During the hearings RCA presented evidence designed to show that the human eye is not at all sensitive to fine detail in color; that the physiology of the eye is such that it can distinguish colors only in coarse detail; for example, the eye can recognize color in a piece of colored string but cannot in the case of a single strand of colored thread held at any appreciable distance from the observer. RCA testified that it devised a system whereby the coarse detail of the picure (e.g. from 0-2 megacycles) is transmitted in color whereas the fine detail in each of the colors (e.g. from 2-4 megacycles) are "mixed" together and transmitted as black and white pictures. The two signals are then transmitted together and give a color picture composed of the low frequency components (0-2 megacycles) for each of the three primary colors and the mixed highs (2-4 megacycles) as black and white.

51. It is claimed that the above process has saved band width. Instead of 12 megacycles being required to transmit three 4-megacycle signals, the requirement is reduced to eight megacycles—2 megacycles for each of the 3 low frequency color signals and 2 megacycles for the mixed highs. Of course, even 8 megacycles are too much for the 4 megacycle band available. RCA endeavors to save the rest of the space by a process known as dot interlace which involves color sampling. Part of the band saving comes from the fact that it requires four fields instead of two in

order to completely sean the picture area once as illustrated in paragraphs 46 and 47. The rest of the apparent band saving comes from permitting a certain amount of cross talk (dilution of color and contrast) in the picture. Each of the 3 signals passes through appropriate electrical filters. These filters separate the low frequency components (0-2 megacycles) out of each of the three color signals. The low frequency color signals are sent to an electronic commutator or sampler. The remaining high frequency components are combined into mixed highs. The sampler op- [fol. 135] erates as an automatic high speed valve that opens and closes at a rate of approximately 11 million times per second. The three color signals enter the sampler. The sampler is so arranged that each 3.6 millionth of a second the sampler opens the valve to the green, red and blue signals in sequence and permits that portion of the particular color signal to pass through to a so-called adder circuit. Thus, instead of transmitting the entire 2-megacycle component for each of the 3 colors, a dot sample is taken at regular intervals. The sampling sequence and the method of dot interlace for the samples taken in successive fields have been described in paragraphs 46 and 47.

52. The mixed highs are also fed into the adder circuit, referred to in the preceding paragraph. The appropriate synchronizing signals [14] are added at this point also and all the signals are then sent to the transmitter.

53. The apparatus utilized by RCA to demonstrate its system has already been described so far as the camera is concerned. The receiving apparatus demonstrated at the original October demonstration consisted of projection receivers, and direct view receivers employing two or three color tubes and dichroic mirrors. The two-tube dichroic mirror receiver, showing two-color television, was not demonstrated again and an RCA witness testified that "the need for a two-color process will be pretty much submerged" when a tri-color tube is developed. Likewise, the projection

[14] In addition to the usual horizontal and vertical synchronizing pulses, an extra synchronizing pulse, consisting of a burst of the sampling frequency, is added after each horizontal pulse during the blanking period. Its purpose is to keep the color sampler at the receiver and the one at the transmitter in step with each other.

receivers were not exhibited again after the original demonstration, and until the April 6, 1950 demonstration all receivers shown by RCA contained dichroic mirrors and three cathode-ray tubes. At the April 6 demonstration, two models of a direct view color tube were demonstrated—one with three electron guns and the other with a single electron gun. RCA described these tubes as follows: In each model the screen of the tube consisted of 117,000 groups with 3 primary color phosphor dots in each group. Between the electron gun and the screen was a mask with 117,000 holes in registry with the dot groups. On the tube with three guns the signals were applied to the three guns in the same manner as to three separate kinescopes. The angle of arrival from each gun was so arranged that each beam hit the hole in the mask in such a way as to line up correctly with the appropriate dot of color phosphor. In the one-gun model the signals were applied to the gun sequentially and the beam was rotated by appropriate deflection circuits keyed to the sampler to insure the correct angle of arrival at the holes in the mask. An RCA witness testified that it was part of the RCA development program to increase the number of picture dots in the tri-color tube with a view to doubling them. The tri-color tubes demonstrated provided a picture about the size of a 14-inch monochrome tube, but RCA testified that there was no reason why a larger tri-color tube could not be made.

[fol. 136] III. Evaluation of the Three Systems

A. *General*

54. In the preceding section of this Report, we had a description of each of the three proposed color systems. In this section of the Report we will evaluate the three systems under each of 9 headings. It should be recognized that when a composite picture is segmented for the purpose of analysis, there is inevitably some overlapping in the categories and some of the characteristics that are included under one heading could just as well have been included under a different heading. The evaluation of the three systems is based upon the testimony and evidence in the record and upon the observations which the Commission had an opportunity to make at the demonstrations held on the record. In making this evaluation consideration is

given to each of the systems as demonstrated in these proceedings and also to potentialities for improvement which may be inherent in the systems, based upon developments disclosed in the record.

B. *Flicker, Motion Continuity, and Allied Effects*

1. *General*

55. There are three subjects which are covered by this heading: large area flicker, small area flicker, and continuity of motion. Large area flicker is a problem in television as in motion pictures. The problem arises from the fact that appearance of motion is achieved by a rapid succession of pictures thrown on the viewing surface. The pictures themselves are illuminated on the viewing surface, but during the period that a picture is being changed the viewing surface is dark. If the rate of change of pictures is too slow, noticeable flicker appears on the screen which is very annoying to the viewer and the brighter the picture the more annoying the flicker. Thus, a fast repetition rate is important to eliminate flicker. The rate must be high enough so that a picture of adequate brightness is possible; the higher the repetition rate the brighter the picture which can be viewed without flicker. In monochrome television a repetition rate of 60 fields per second is employed.[15]

56. Small area flicker is a problem for television but not for motion pictures. In motion pictures a complete still picture is transmitted as a whole, but in television adjacent lines on the face of the tube are scanned during different fields as a result of line interlacing and this gives rise to interline flicker. In dot interlace television systems there is, in addition, inter-dot flicker. Both are considered under small area flicker.

57. The problem of continuity of motion has two aspects. First, in order to achieve smoothness of motion and avoid jerkiness, the picture repetition rate must be sufficiently

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[15] The ability to observe flicker varies from person to person. It is affected by the amount of illumination in the room, the highlight brightness of the picture, the field rate, the luminosity in case of color, the relative duration of light to darkness, and also by the ratio between the picture height and the distance of the viewer from the screen.

high so that the persistence of vision in the eye creates the illusion of smooth motion. The second aspect of the problem deals with the ability of the system to portray [fol. 137] moving objects. Where a moving object is being scanned, it is apparent that it will be in a slightly different position in each of successive fields. There is a tendency for moving objects to be smeared and for detail to be lost. The faster the field repetition rate, the better the results that can be expected with respect to continuity of motion.

58. In order to understand the potentialities for improvement in the three systems so far as flicker is concerned, an understanding of the decay nature of phosphors is necessary. The phosphor utilized on the receiving tubes in television receivers has the property of being illuminated when hit by the electron scanning beam. The illumination remains for a time after the scanning beam has moved on, but shortly thereafter the illumination ceases. This cessation is not abrupt but gradual; hence the expression, the "decay" characteristics of phosphor. "Slow decay phosphors" and "long persistence phosphors" are correlative terms and are used interchangeably in this Report.

59. In practice, the phosphors presently utilized are fast decay phosphors. It can readily be seen that by utilizing slow decay phosphors, there is a good deal of room for reducing the flicker problem without increasing the field rate, or conversely to reduce the field rate and permit an increase in resolution. This is due to the fact that slow decay phosphors by their nature increase the time that the tube face is illuminated and decrease the time that it is dark. Since flicker is produced by the alternation of light and dark time on the viewing surface, anything that decreases the amount of dark on the viewing surface, has an effect so far as flicker is concerned similar to increasing the repetition rate. There has been no incentive for the utilization of slow decay phosphors in our present system since the repetition rate is high enough to provide adequate brightness without flicker even when fast decay phosphors are used.

60. There was testimony in the record concerning long persistence phosphors and a demonstration of one such phosphor was held on the record in the CBS Laboratory in New York on April 26, 1950. The tri-color tubes shown at the RCA demonstration of April 6, also had long persistence phosphors. While the Commission is anxious to

see further testing conducted, we are nevertheless able to find on the basis of this record that long persistence phosphors are practical and can be taken into account in considering the potentialities of the systems under consideration.

[fol 138] 61. During the hearing frequent reference was made to receiver storage tubes. A storage tube is a specialized long persistence tube. It has the property that once it has been illuminated, it will retain that level of illumination until replaced by a different level of illumination; the change is instantaneous. If such a tube were developed for use in home television, it would reduce flicker substantially since it would shorten the blackout period on the viewing screen. However, no demonstration was made of such a tube nor was any evidence offered that such a tube has been developed, or could be developed within the foreseeable future. Accordingly, we are unable on this record to take storage tubes into account in arriving at our decision.

2. *The CTI System*

62. As has been indicated, the susceptibility of a television system to large area flicker depends on the number of fields per second. The CTI system has a field rate of 60 per second, the same as the present television system and should have about the same performance characteristics on this score when showing black and white picture. So far as color pictures are concerned, insufficient evidence was offered as to whether the flicker characteristics are the same as for black and white pictures. There was no flicker observed at any of the demonstrations on the record but it should be noted that the pictures had very low illumination.

63. There is a problem in the CTI system so far as small area flicker is concerned. In all of the demonstrations there was a most noticeable line crawl or jitter, which seriously marred the quality of the transmitted picture. The line crawl apparently results from the fact that there is a relatively low line repetition rate in each of the primaries and the eye thus tends to follow each line down. As was pointed out above, line crawl is inherent in a line sequential system where the shift in initiation of colors is uniform. The purpose of the various shifts developed by CTI was to eliminate the problem, but they did not accomplish this purpose. Although the last shift demonstrated—the interlaced shift—

may have reduced line crawl somewhat, it still remains to a prominent degree. This line crawl or jitter was noticeable even with the very low level of picture illumination that CTI was able to produce on its projection receiver. Since line crawl is a flicker phenomenon, it can be expected to be intensified with increased brightness. This turned out to be the case at the San Francisco demonstration where the CTI color transmissions utilizing the interlaced shift were received on a 3-tube, dichroic mirror type of receiver. This receiver produced higher brightnesses than the other CTI receivers and, as was to be expected, the line crawl was more noticeable. It can be expected that the development of tubes with long persistence phosphors would reduce the line crawl but to what extent is not known since no demonstration has been held and line crawl may very well be an inherent defect of the CTI line sequential system. Moreover, it should be noted that if the phosphor was of long enough persistence to eliminate the problem of line crawl, the effect on color fidelity and the portrayal of objects in motion would have to be carefully evaluated.

[fol. 139] 64. So far as continuity of motion is concerned, the CTI system produces no more than 10 color pictures per second. No problem was evident at the demonstrations as to continuity of motion but such demonstrations involved only pictures of low illumination.

3. *The CBS System*

65. The CBS system has a field repetition rate of 144 per second. However, the primary color repetition rate is 48 per second. It is this latter figure that is ultilized in assessing the susceptibility of the system to large area flicker in color pictures. Why this is so can be illustrated by the situation where a scene is being scanned that has large areas of green in it—or any other single primary. When the field containing the green components is on the screen, the tube will be illuminated. The tube face will be relatively dark thereafter until the green field appears again in 1/48 of a second. Thus, in effect there is a repetition rate of 48 per second so far as flicker is concerned under the circumstances described above.[16]

[16] When a black and white picture is shown, the susceptibility to flicker would probably be less than for a color picture.

66. CBS testified that the flicker in its disc type receiver became noticeable at 24 feet lamberts[17] (for a 7 to 1 viewing distance) and that flicker did not become objectionable until a higher figure of brightness was reached. Flicker is a physiological phenomenon that varies from person to person and hence is not capable of exact measurement. However, on the basis of the record, the Commission is able to find that flicker is not objectionable on the CBS disc type receiver up to highlight brightnesses of from 20 to 30 foot lamberts. The present black and white television system with a field rate of 60 has a flicker threshold many times that of the 24 foot lambert figure mentioned above, although there is serious doubt as to whether such highlight brightnesses are used by the public.[18] If tubes with long persistence phosphors were utilized, it would be possible to [fol. 140] increase brightness several fold with no flicker problem. A CBS witness testified that brightness could be increased to more than 100 foot lamberts without flicker, but it is not possible to predict the exact extent of such improvement without further testing. It should be noted, however, that there is a limitation on the use of very long

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[17] A foot lambert is the unit for measuring the brightness of light reflected from a surface.

[18] The only testimony on this subject was given by John V. L. Hogan, Vice-Chairman of JTAC, testifying as a witness for CBS, and T. T. Goldsmith of DuMont. Hogan's testimony was based upon a survey in stores of 75 new receivers of various makes which showed that only 0.7 of 1% of such sets had a highlight brightness reading of between 28 and 30 foot lamberts; the largest percentage was between 18 and 20 foot lamberts; and the average was 17. Goldsmith testified on direct examination that he had measured DuMont receivers and that 120 foot lamberts were typical. On cross examination, he testified that the average was 50 foot lamberts. The Commission does not believe that there is sufficient evidence in this record upon which to base a finding as to the level of brightnesses at which sets are operated in the home. Nor is it necessary that we do so because, as will be pointed out below (Paragraph 74) 20 to 30 foot lamberts are sufficient for disc type receivers and long persistence phosphors make higher brightnesses without flicker possible on other types of receivers.

persistence phosphors with a disc type receiver. To illustrate, when a field is scanned in red, the red filter is in front of the tube. In the next 1/144 of a second, the blue filter is in front of the tube. If there is still any substantial illumination left, it will merge with the illumination from the blue signal.

67. No problem of small area flicker was observed at any of the demonstrations on the record. However, if horizontal interlace were utilized, a certain amount of small area flicker might appear which can best be described as dot motion or twinkle. Since it is a flicker phenomenon, tubes with long persistence phosphors should minimize the problem. The magnitude of this flicker cannot be ascertained without further study.

68. As to continuity of motion, no problem was experienced at any of the demonstrations on the record.

4. *The RCA System*

69. The RCA system has 60 fields per second and its performance as to large area flicker is the same as the present system, so far as black and white pictures are concerned. So far as color pictures are concerned, insufficient evidence was offered as to whether the flicker characteristics are the same as for black and white pictures. There was no flicker observed at any of the demonstrations on the record, but it should be noted that the pictures had very low illumination.

70. At the demonstrations on the record small area flicker in the form of dot motion or twinkle has been observed. How serious a problem this is cannot be entirely ascertained at this time since the RCA demonstrations produced only a dim picture. With increase in brightness of the picture to the level necessary for home use, the effect will be accentuated, although it is possible that this effect may be overcome or minimized by the utilization of tubes with long persistence phosphors. The extent of such improvement cannot be determined without further testing. If the phosphor is of long enough persistence to reduce substantially the above defects, the effect on color fidelity and the portrayal of objects in motion would have to be carefully evaluated.

71. As to continuity of motion, no problem was observed at any of the demonstrations on the record with the low level of illumination present in the picture.

[fol. 141] C. *Brightness—Contrast*

1. *General*

72. Under the preceding heading we discussed the problem of brightness as it related to the question of flicker. In this part brightness will be considered from the point of view of adequacy—is the picture bright enough so as to give a sufficient contrast range [19] and so as to be capable of being viewed under normal home viewing conditions? There is no precise ratio for satisfactory contrast; it is a matter of choice with the individual viewer. In general, the wider the contrast range the better, since there is more flexibility for reproducing shades of gray in black and white pictures and shadings of color in a color picture. Based upon the demonstrations on the record, a contrast ratio of 30 to 1 for color pictures produces a very satisfactory picture.[20] However, with receivers operating in normally lighted rooms with brightnesses of the order indicated in the Hogan testimony, a much lower contrast ratio is achieved. The Commission has no reason to believe that these pictures are not satisfactory to the viewers.

2. *The CTI System*

73. At none of the demonstrations did any of the CTI receivers possess sufficient brightness. The highest measured brightness of a CTI receiver was 4 foot lamberts, although an RCA type of receiving equipment employing three tubes with dichroic mirrors was able to produce a brighter picture at the San Francisco demonstration. The CTI pictures were so dim that all CTI demonstrations had

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[19] The contrast range is determined by the ratio of brightness between the brightest and darkest portions of a picture. The brightest portion of the picture is determined by the amount of illumination which is produced by the scanning beam. The darkest portion is determined by the amount of light which the tube surface will reflect; the light in general comes from illumination in the room where the picture is being viewed.

[20] So far as black and white pictures are concerned, it is possible that a higher contract range is required since color by its nature gives contrast to a picture.

to be conducted in a room that was virtually dark. It should be noted that the failure to produce brighter pictures is undoubtedly due in large measure to the particular type of apparatus used and there is no reason to believe that the CTI system is incapable of generating much brighter pictures. However, as has already been indicated, higher brightnesses complicate the problem of line crawl which is already serious even at the low level of illumination demonstrated by the CTI system.

[fol. 142] *3. The CBS System*

74. The amount of brightness which can effectively be utilized is determined by the flicker level. This figure is 20 to 30 foot lamberts on CBS disc receivers. The maximum figure achieved for a disc receiver at a demonstration on the record was 22 foot lamberts. We are of the opinion that the color picture so produced is bright enough and has sufficient contrast range to be entirely adequate for use in the home under normal viewing conditions. Indeed, the CBS demonstrations were the only ones that were conducted in a lighted room and during one of the demonstrations a light from a 300-watt lamp was thrown directly on the face of the receiver without seriously affecting the quality of the picture. This is possible because the disc operates as a two-way filter so far as illumination in the room is concerned; that is, any light that is reflected from the tube which originates in the room must pass through the disc on its way to the tube and the light that is so reflected must pass through the disc again on its way out. By way of illustration, if the disc ultilized permits 10% of the light to pass through, filtering out 90%, it would be possible to view a 20-foot lambert picture on the CBS disc receiver in a room with an illumination of 67 foot lamberts and still retain a contrast ratio of 30 to 1.[21]

75. As was pointed out previously, higher brightnesses without flicker are possible in the CBS system by the utiliza-

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[21] For a 20-foot lambert picture, the reflected light cannot exceed 2/3 of a foot lambert on a 30 to 1 ratio. If the ambient illumination at the receiver is 67 foot lamberts, this is reduced to 6.7 foot lamberts on the way through the disc to the tube and this in turn is reduced to 0.67 foot lamberts on the way out through the disc.

tion of tubes with long persistence phosphors. Tubes with long persistence phosphors cannot be utilized on disc receivers without a problem of color contamination, and the disc would not be present to serve as a filter. The viewer could have a neutral density filter on his receiver to improve contrast in the same way as on a black and white receiver.

4. *The RCA System*

76. At none of the demonstrations on the record did any of the RCA color receivers produce sufficient illumination for ordinary home use. Indeed, all of the RCA demonstrations on the record were conducted in a room with virtually no illumination. While equipment can undoubtedly be developed that will produce higher brightnesses, there is some doubt—which can be resolved only by further testing—as to whether the duty cycle of the RCA system will permit much higher brightnesses on the tri-color tube. Moreover, the RCA system has difficulty in maintaining adequate contrast, particularly in small areas. This defect appears to be due to the use of the mixed highs principle, cross talk and to the efforts made to smooth out the dots as much as possible so as to avoid the appearance of dot structure in the picture.

[fol. 143] D. *Superposition of Color Images*

1. *General*

77. There are three subjects covered by this heading: registration, color breakup, and color fringing. The problem of registration arises from the fact that since color television involves the transmission of three separate pictures in different colors, which are then combined into one color picture, it is apparent that the three separate pictures must have the same size and shape and must appear to lie directly one over the other if a satisfactory picture is to result. As can be seen, this must be so both for the electrical and optical components of each of the three pictures. When this is successfully accomplished, the pictures are said to be in "register" or the "registration" is satisfactory. Otherwise, registration is not satisfactory and both resolution and color fidelity are adversely affected.

78. Color breakup may occur when the eye moves while watching a color picture and causes the viewer to see the

separate primary colors. It is caused by the fact that successive fields occupy slightly different positions on the retina of the eye. Color fringing appears in the form of fringes along the edge of objects and it usually occurs when a rapidly moving object is televised in color.[22]

2. *The CTI System*

79. There is a severe registration problem at the camera and receiver. At the camera end the optical system must be so adjusted and maintained that the image being transmitted falls upon the three separate color bands of the tube in exactly the same relative position. Moreover, each color band must be so constructed and maintained that it will cause the electron scanning beam to generate signals of exactly the same linearity as the other two bands. For example, if an object an inch square were being scanned, if one band produced signals that reproduced the object as ⅞ of an inch, the second band an inch, and the third band 1⅛ inch, it is obvious that reduction in resolution and color distortion would result. At the receiver end, the same precise adjustments must be made. It is exceedingly difficult to construct equipment which is as precise and uniform in response as required for accurate registration. It is even more difficult to maintain the precision as time goes along, for the electrical component parts age. The difficulty of securing accurate registration is illustrated by the fact that there was evidence of faulty registration at every one of the CTI demonstrations held on the record. And this occurred when the equipment was in control of trained technicians. The results would undoubtedly eb much worse if the receivers were in a home, operated by untrained people, and had not been adjusted to optimum operating conditions just prior to the demonstration but had been in operation for a substantial period of time with no service adjustment.

[fol. 144] 80. Color breakup has not been observed at any of the demonstrations on the record; it does not appear to be a problem in a line sequential system. Color fringing has likewise not been observed so far as moving objects are concerned but line interlace causes color fringing on nearly

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[22] An effect similar to color fringing is caused by misregistration.

horizontal lines of other than primary colors. In addition, an effect similar to color fringing was apparent due to misregistration.

3. *The CBS System*

81. The CBS system is not troubled by other than minor registration problems either at the camera or receiver. These minor problems arise from power supply hum, stray fields, and vibration but they are easily cured. The reason why no fundamental registration problem exists is that only a single tube is utilized both at the camera and disc type receiver; the field sequential system is the only one that can do so.[23] Hence, the response of the scanning beam is the same for each color and each field. At none of the demonstrations on the record did the Commission observe any evidence of misregistration.

82. Color breakup and color fringing were observed at the demonstration on the disc receivers. The use of tubes with long persistence phosphors should minimize color breakup at the receiver. Color fringing, moreover, will still occur due to the use of the color disc at the camera.

4. *The RCA System*

83. Registration, both electrical and optical, is a severe problem both at the camera and receiver. At the camera this is due to the fact that three separate pick-up tubes are utilized. The optical system must be so adjusted and maintained that the image being scanned falls upon the three tubes in exactly the same relative position. Moreover, three separate electrical signals of exactly the same linearity must be generated. Even if equipment is originally constructed that could meet this test, it is extremely doubtful that such precision could be maintained. The rate of deterioration is likely to differ for each of the three tubes. The same problems are also present on the three tube receiver. RCA demonstrated a receiver employing a single tri-color tube in which it was claimed correct registration was built into the tube.[24] It should be noted, however, that

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[23] As will be pointed out later, if a tri-color tube is developed which can be utilized without the disc, it will have to have correct registration built into it to be capable of use.

[24] See Paragraph 53.

at all of the demonstrations on the record, there was evidence of faulty registration. This was also true of the demonstration on April 6 where the tri-color tube was shown. Of course, such misregistration may have been the fault of the camera rather than the receiver since a mis- [fol. 145] registered picture results if there is misregistration in either the optical or electrical aspects of the camera or receiver. Hence, even if the tri-color tube does have correct registration built into it, misregistration results at the receiver unless misregistration is corrected at the camera. The problem has not been solved by RCA at any of the demonstrations on the record when only indoor equipment was utilized. The problem by its nature is bound to be far more difficult in the case of outdoor pickups and RCA has not demonstrated any outdoor pickup camera. RCA did testify that a single tri-color tube could be developed for the camera which would have correct registration built into it. No such tube was demonstrated nor was there any testimony that one had been constructed. It is difficult for the Commission to see how the RCA system could utilize such a tube even if one were constructed. The principle of mixed highs upon which RCA relies so heavily requires by its very nature a simultaneous camera pickup of 3 color signals.

84. There should be no problem of color breakup or color fringing due to motion in the RCA system. However, faulty registration of pictures observed at the demonstrations produces an effect similar to color fringing.

E. *Color Fidelity*

1. *The CTI System*

85. At all of the demonstrations on the record, CTI had difficulty with color fidelity because of faulty registration. There was also difficulty in accurately reproducing skin tones. Moreover, the low levels of illumination at which the pictures were shown rendered difficult a judgment as to the quality of the color fidelity.

2. *The CBS System*

86. The color fidelity of the CBS system as demonstrated on the disc receiver has been of a uniformly high quality. No determination can be made on the record as to whether

receivers utilizing a direct view tri-color tube can achieve the same uniform high quality of color fidelity as disc receivers. This is due to the fact that there is no evidence in this record that color phosphor surfaces have been developed to the point where they produce colors as accurately as a filter, and also because a tube utilizing separate color phosphors loses the advantage of the use of a single viewing surface for all three colors.

3. *The RCA System*

87. At all of the demonstrations on the record, RCA had difficulty producing a color picture with adequate color fidelity.[25] The difficulty undoubtedly arises from several [fol. 146] factors which are part of the RCA dot sequential system. In the first place, registration is most difficult to maintain and when misregistration occurs there is color contamination and a loss in resolution. In the second place, color control is exceedingly difficult to maintain. A time error of only 1/11,000,000 of a second in the sampler, results in the wrong color being transmitted or received. In the third place, the utilization of mixed highs, cross talk, and the fact that the colored dots are larger than a single picture element appear to prevent the production of color detail in small areas over the entire picture. In the fourth place, the fact that the three primary color images are scanned on three separate surfaces at the camera, makes it exceedingly difficult to obtain uniform sensitivity for all colors over the whole picture area. The result was that color fidelity of a high quality was not consistently achieved at any of the demonstrations on the record and in particular there was no real success in correctly reproducing skin tones. All of these difficulties will undoubtedly be aggravated on outdoor pickups as will be more fully explained in paragraph 118. So far as the tri-color receiving tube is concerned, the RCA picture also suffers from the limitations as to color fidelity which are involved in the use of color phosphors rather than filters.

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[25] Although there is some testimony that at times the color fidelity of the RCA picture was adequate, this was achieved either at a special demonstration not on the record or sporadically on the record.

F. *Resolution*

1. *General*

88. Since a television picture is scanned line by line, it is apparent that the more lines per second that are scanned, the finer the vertical detail that can be portrayed. Hence, one of the methods commonly utilized to measure the definition capabilities of a system is geometrical resolution—the number of lines which the system can provide. In practice, resolution is determined by readings on a test pattern; vertical resolution is read on the horizontal wedges and horizontal resolution on the vertical wedges. These test patterns are principally of use in reading resolution of a black and white picture. For color pictures, an adequate test pattern must still be developed with wedges and lines in color. Besides resolution there are other factors which enter into the apparent definition of a picture, such as contrast, sharpness of the picture, etc. However, these are subjective factors and unlike resolution are not susceptible of ready measurement. Nevertheless, they are important and are the subject of consideration under the next heading. Moreover, color itself gives realism to pictures, affords better contrast, and thus improves apparent definition.

2. *The CTI System*

89. In theory the resolution of the CTI system should approach that of the present system. This has not been the case, for at none of the demonstrations on the record did CTI produce a picture which could compare in resolution with black and white television. The reason for this lies in the faulty registration which has been observed at each demonstration and in the line crawl which is present in the system.

[fol. 147]

3. *The CBS System*

90. The CBS system produces 405 lines per picture as compared with 525 lines per picture for the present system. Hence, as is to be expected, the vertical resolution of the CBS picture is below that of the present system. The use of 144 fields per second, with a resulting line scanning rate of 29,160 per second, results in a loss of horizontal resolution. There is a reduction in vertical resolution by

23% and horizontal resolution by 46% as compared with the present system. By utilizing horizontal interlace and retaining the horizontal scanning rate suggested by CBS, the vertical resolution would still be reduced by 23% but the horizontal resolution would be approximately the same as monochrome. Further testing is required in order to determine whether this increase can be achieved in practice.

4. *The RCA System*

91. Although the RCA system produces lines at the same rate as the black and white system, its resolution even in theory is not equal to that of the present system for all types of scenes. The vertical resolution should approach that of the present system but the horizontal resolution ranges between 67% and 100% of the present system. This is probably due to cross talk and the use of mixed highs. Moreover, if in the scene being scanned there are two adjacent areas of different colors which are of equal intensity, no mixed highs would be generated and in this type of situation the horizontal resolution could be reduced to as little as 33%. Finally, in practice, the RCA resolution has suffered from the misregistration which has been present at each of the demonstrations on the record.

G. *Picture Texture (Structural)*

1. *General*

92. Under the previous headings we have described the several qualitative aspects of a color television picture seriatim. Under this heading we will evaluate the over-all quality of the picture.

2. *The CTI System*

93. It is difficult to make a final judgment as to the picture texture of the CTI system since virtually all of the pictures were shown on a projection receiver at low levels of illumination. Projection receivers by their very nature produce "soft" pictures as compared with direct view receivers. However, in the CTI system line structure is prominently apparent in areas of red and green primary colors and line crawl is visible over the entire picture.